

METHOD AND DEVICE FOR DATA DECODINGField of the Invention

The present invention relates to a method for data decoding, comprising decoding data stored in a partial area of a coding pattern on a surface, based on a recorded image of the partial area, said coding pattern containing elements which each have at least two possible decoding values. The invention also relates to a device for data decoding, comprising processing means for decoding of data which is stored in a partial area of a coding pattern on a surface. Moreover the invention relates to a memory medium on which is stored a computer program with instructions for data decoding based on an image. Finally, the invention also concerns use of probability calculations in data decoding based on an image of a coding pattern.

Background Art

In many situations it is desirable to be able to decode data stored in coded form on a product. One example of such data decoding is to determine the position on a surface provided with a coding pattern. Such position determination is useful, for instance, when using a reading pen on a writing surface.

Applicant's Patent Publication WO 01/26032, which is herewith incorporated by reference, describes a device for position determination and a product that has a surface that is provided with a coding pattern. The device is arranged to record an image of the surface, to locate a predetermined number of symbols in the image, to determine the value of each of the symbols and to determine its position on the surface based on these values.

There are many other types of coding patterns in the form of position codes, for example, those in which each position is coded by a complex symbol with a special appearance.

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A problem in decoding the known types of coding patterns is that the values of the symbols cannot always be determined with full accuracy. When the coding pattern is printed on a surface, the limited resolution of printers may imply that the symbols are not printed completely exactly. The symbols can, for example, be printed somewhat deformed or somewhat displaced from their "nominal" location. If it is the shape or location of the symbol that determines its value, the deformation and the displacement, respectively, mean that it may be difficult to determine the value of the symbol unambiguously.

It sometimes also happens that a symbol is not printed at all.

Another problem may arise if the coding pattern is printed on a surface that has a structure of its own that can interfere with the location of symbols in the recorded image. Structures in the surface can then be perceived as symbols by a device for data decoding. It can also happen that there are impurities, for instance in the form of dust, on the surface on which the coding pattern is printed. These impurities may give rise to noise symbols in the recorded image, which noise symbols may then by mistake be identified as symbols in the coding pattern. Also sensor noise from a sensor for recording the image may cause noise symbols in the image. Noise symbols in the recorded image may also originate from a defect on one of the components in the device, for instance damaged pixels in the sensor. On account of the above reasons there is therefore a risk that data cannot be decoded from the coding pattern in a recorded image.

Summary of the Invention

An object of the present invention is to wholly or partly overcome the above-mentioned problems relating to prior art.

According to the invention this object is achieved by means of a method, a device, a memory medium, and use, which have the features that are stated in the indepen-

dent claims. Preferred embodiments are stated in the dependent claims.

5 A basic concept of the present invention is to use probability calculations in decoding of data which is stored in a coding pattern on a surface.

According to a first aspect, the present invention relates to a method for decoding of data. The method comprises decoding data stored in a partial area of a coding pattern on a surface, based on a recorded image of the
10 partial area. The coding pattern contains elements, which each have at least two possible decoding values. The method further comprises identifying in the image a plurality of said elements, calculating, for each identified element, an associated value probability for each possible decoding value that the element has this decoding
15 value, and performing decoding of data based on the decoding values and the corresponding value probabilities.

For the reasons discussed above, the coding pattern
20 on a surface, and/or the imaging of the same, is usually not completely perfect. One single decoding value for an element can usually not be determined with complete certainty as there is a possibility that the element has another of the possible decoding values. According to the
25 invention, for each element and for each of the decoding values, a value probability is therefore calculated that the element has that decoding value. If an element is determined unambiguously, then the value probability that corresponds to the unambiguously determined decoding
30 value of the element will be maximum, while the other value probabilities for the element are zero. The more uncertain the decoding value of an element, the less difference there is between its value probabilities. If an element is missing in one place in the coding pattern,
35 the value probabilities for the element will therefore be equally high. The present invention thus enables a relatively robust decoding of the coding pattern.

In the recorded image, more than a predetermined number of elements that are required for decoding of data may often be identified. The predetermined number of elements which may contribute most information in decoding can therefore be selected. As stated above, these elements are those having a dominating value probability for one of the decoding values. Consequently the chance increases that data can be decoded based on the recorded image since an element contributing little information can be sorted out.

The method may further comprise decoding at least a first set of decoding values for the predetermined number of identified elements.

The method may further comprise calculating sequence probabilities for a sequence of elements in the recorded partial area in the image. For instance, if the predetermined number of identified elements is a matrix, the sequence of elements can be the elements in a column or row in the matrix. The sequence probabilities can be calculated based on the value probabilities for the decoding values in the first set that correspond to the elements in the sequence. A value probability can be calculated for each of a plurality of a permissible combinations of decoding values. For each element, each of the possible decoding values corresponds to a value probability. The sequence probability for a combination may be determined based on the value probabilities for the decoding values which constitute the combination. In the same way as a value probability for an element corresponds to the element having the corresponding element value, a sequence probability for a sequence of elements corresponds to the sequence consisting of the corresponding combination. Of course, there are other ways than that described above in which sequence probabilities can be calculated.

The method may comprise selecting one of the possible decoding values for each of the elements which correspond to the first set of decoding values. The

selection can be made based on a condition, given by the coding pattern, for the relation between the decoding values of the elements. The condition conveniently indicates which combinations of decoding values may exist among the elements in the coding pattern in the recorded image. In other words, the condition is given by how the used coding pattern is made up. The condition for existing combinations can be given at a global level, i.e. seen over all elements in the image, or at a local level, i.e. over an ensemble of elements in the image, for instance by columns and/or rows. Probability calculations are used to combine the information in the image, corresponding to said condition, so that the decoding values of the elements can be selected based on the probability calculations, within the scope of the condition.

The condition may indicate the above-discussed permissible combinations of decoding values.

Coding patterns that are used in connection with the present invention can usually be recorded "from more than one direction". This means that the coding pattern in the recorded image can be rotated in different ways. The result of a decoding of data depends upon the rotation of the coding pattern. For this reason, the method according to the invention may comprise carrying out the decoding based on rotation probabilities. The rotation probabilities correspond to different rotations or orientations of the recorded image, i.e. different rotations of the coding pattern. For each of the different rotations of the image, a rotation probability can be calculated. This can be done based on the sequence probabilities or value probabilities of the decoding values for the identified elements. Then data may be decoded based on the rotation of the coding pattern which gives the highest rotation probability. This step implies that the decoding of data is not affected by a device according to the invention being rotated in relation to the surface during the position determination.

According to a second aspect, the invention relates to a device for data decoding, comprising processing means for decoding of data which is stored in a partial area of a coding pattern on a surface, based on a recorded image of the partial area, which coding pattern contains elements, which each have at least two possible decoding values. The device is arranged to identify in the image a plurality of said elements, calculate for each identified element an associated value probability for each possible decoding value that the element defines this decoding value, and carry out decoding of data based on the decoding values and the corresponding value probabilities.

The image can be recorded by a sensor. The sensor can be integrated with the device for data decoding or be positioned in a separate unit, from which the device receives the recorded image.

According to a third aspect, the invention relates to a memory medium on which is stored a computer program with instructions for data decoding, based on an image.

According to a fourth aspect, the invention relates to use of probability calculations in data decoding based on an image of a coding pattern.

The method can be implemented as a computer program which is stored in the memory of the device and executed in the processor or in an external device. Alternatively, the method can be implemented completely or partially in the form of an application-specific circuit, such as an ASIC, or in the form of digital or analogue circuits or of some suitable combination thereof.

The features that were discussed in connection with the method above are of course transferable to the device, the memory medium and the use according to the invention.

The above features can of course be combined in the same embodiment.

Brief Description of the Drawings

The present invention will now be described in more detail by way of embodiments and with reference to the accompanying drawings, in which

Fig. 1 shows a device for data decoding.

5 Fig. 2 shows a flow chart describing a decoding example.

Fig. 3a shows a sheet of paper provided with a first type of coding pattern.

10 Fig. 3 shows an enlargement of part of the coding pattern in Fig. 3a.

Fig. 4 shows four ideal locations of a mark in a coding pattern.

Fig. 5 shows how value probabilities for a mark are calculated.

15 Fig. 6 shows how value probabilities for an element are calculated.

Fig. 7 illustrates the creation of a first and a second matrix.

Fig. 8 shows a cyclic main number sequence.

20 Fig. 9 illustrates the calculation of a sequence probability.

Fig. 10 illustrates steps in the decoding of data.

Fig. 11 illustrates rotation of a coding pattern.

Fig. 12 shows a second type of coding pattern.

25 Fig. 13 shows two more examples of coding patterns.

Detailed Description of the Invention

Fig. 1 shows a device 1 for data decoding. In this example, the device 1 is used to decode or determine a position. In this case data is more specifically two coordinates defining a position. The device comprises a casing 2 which is approximately of the same shape as a pen. In the short side of the casing there is an opening 3. The short side is intended to abut against or to be held a short distance from a surface 4, which is provided with a coding pattern (not shown) which stores data to be decoded. The device 1 comprises at least one light-

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emitting diode 5 for illuminating the surface 4, and a light-sensitive area sensor 6, for example a CCD or CMOS image sensor, for recording a two-dimensional digital image of a partial area of the coding pattern on the surface 4. Optionally, the device 1 can also contain a lens system 7.

The power supply for the device 1 is obtained from a battery 8, which is mounted in a separate compartment in the casing 2.

The device 1 further comprises image-processing means 9 for determining the position on the basis of the image recorded by the sensor 6 and, more specifically, a processor unit 10 which is programmed to record images from the sensor 6 and to carry out position determination on the basis of these images.

In this example, the device 1 also comprises a pen point 11, by means of which ordinary pigment-based writing can be written on the surface 4. The pen point 11 can be extendable and retractable so that the user can control whether or not it is to be used. In certain applications, the device does not need to have a pen point at all.

The device 1 can further comprise buttons 12, by means of which the device can be activated and controlled. It can also comprise a transceiver 13 for wireless transmission, for example using infrared light or radio waves, of information to and from the device, and a display 14 for displaying information based on decoded data.

Now follows a description, with reference to the flow chart in Fig. 2, of an example of how a coding pattern can be decoded by means of probability calculations. The coding pattern to be decoded is of the type described in Applicant's WO 01/26032.

Fig. 3a shows a sheet of paper 15 that has a surface 16 that is provided with a coding pattern in the form of an optically readable position code 17. The position code consists of marks 18 and is greatly enlarged for the sake

of clarity. Fig. 3b shows a further enlarged part 19 of the position code 17 in Fig. 3a. The device is arranged to record an image of a partial area of the position code (step A), to identify a plurality of marks 18 in the
5 image (step B) and to fit to the image a reference system in the form of a raster (step C) with raster lines 21 that intersect at raster points 22. The fitting is carried out in such a way that each of the marks 18 is associated with a raster point 22. For example, the mark 23
10 is associated with the raster point 24. Consequently the raster fitting makes it possible to determine to which raster point each mark belongs. In this example, the raster has the form of a square grid, but also other forms are possible. Applicant's Applications WO 01/75783,
15 WO 01/26034 and SE 0104088-0, which are herewith incorporated by reference, disclose in more detail fitting of a raster to marks in an image.

In the "ideal" coding pattern, one and only one mark is associated with each raster point. Owing to deformations and deficiencies in the imaging of the coding pattern, it may be difficult to determine in an image of the
20 coding pattern which marks belong to the coding pattern and which of a plurality of marks is the one that is to be associated with a certain raster point. For this reason, it is possible to associate in this example a plurality of marks with one and the same raster point in the decoding of data. The marks associated with a raster point together form an element belonging to the raster point.

30 In the coding pattern in this example, the value of the marks 18 is defined by their displacement in relation to the raster points 22 with which they are associated. More specifically, it is the position of a point of a mark relative to a raster point that defines the value
35 of the mark. This point is typically the main point of the mark. In the coding pattern in this example, there are four ideal locations for each mark. These locations

are on each of the four raster lines 21 extending from the raster point 22 with which the mark is associated. The locations are situated at an equal distance from the raster point. The ideal locations 25 for a mark are shown enlarged in Figs 4a-d. They have the value "0" in Fig. 4a, the value "1" in Fig. 4b, the value "2" in Fig. 4c and the value "3" in Fig. 4d. Each mark can thus represent four different values "0-3".

For various reasons, the marks identified in the recorded image often do not have an ideal location. In many cases it can therefore be difficult to unambiguously determine one value for a mark. Because of this, the device is arranged to calculate, for each identified mark, an associated value probability for each value "0-3" that the mark defines this value (step D). The value probabilities for each mark are a decreasing function of the distances 26 from the mark 27 to each of its ideal locations 25, see Fig. 5, or more specifically, typically from the main point of the mark 27 to each ideal location. The marks can be assumed to be normally distributed around the ideal locations. This means that the value probabilities, $P(d_i)$, can be calculated by the formula $P(d_i) = k \exp(-(d_i)^2/v)$, where k = a constant, d_i = the distance from a mark to an ideal location and v = a constant, in this example the variance of the distance. The variance can be determined empirically. Four value probabilities can thus be calculated for each mark. It sometimes happens that a mark is found in the centre of a raster point. In these cases, the four value probabilities for the mark will be equal, since the distances from the mark to each of the ideal locations are equally large. The case when there is no mark associated with a raster point, i.e. the associated element contains zero marks, is treated as if there was a mark in the centre of the raster point, that is the value probabilities are equal.

If there is more than one mark, for example three, associated with a raster point, i.e. three marks in the associated element, there are a total of 3×4 value probabilities for the raster point or element. The device is
 5 therefore arranged to determine, for each raster point or element and for each value, a value probability that the marks associated with the raster point together define this value (step E). These value probabilities for a raster point could thus also be called raster point probabilities. By calculating the value probabilities for
 10 the raster points, all the marks in the recorded image may be taken into consideration in the position determination and the risk of information being lost is minimised. Since the above means that for each element, value
 15 probabilities are calculated that the element defines each of the values, the values "0"-"3" are called element values in the rest of the description.

The value probabilities for an element can be determined by the value probabilities for the marks in the
 20 element being compared, the highest value probability being selected for each possible element value. Alternatively, the value probabilities for the element can be weighted sums of the value probabilities for each of the possible element values for the marks in the element. The
 25 value probabilities for the element can, of course, also be determined in other ways than those mentioned above.

Calculation of the value probabilities for an element in this example is illustrated by means of the number example in Fig. 6. Fig. 6a shows a raster point 22
 30 with two associated marks 28 and 29. The marks 28 and 29 together constitute the element belonging to the raster point 22. The Tables 30 and 31 in Fig. 6b contain the value probabilities P_1 for the possible values of the respective marks. The Table 32 in Fig. 6c contains the
 35 resulting value probabilities P_2 for the possible element values of the element. In this example, the value probabilities for the element are relative. Alternatively,

they can instead be normalised in a suitable way. If there is only one mark associated with a raster point, i.e. one mark in the associated element, the value probabilities for the mark and the element are obviously the same.

When recording an image, the distance from the device to the surface influences how large a part of the position code is recorded and thereby also how large a raster can be fitted to the image. For converting the image into a position, a predetermined number of elements is used, which in this example is 8x8 elements. If more than 8x8 raster points have been fitted to the image, an excess of elements is thus identified. The device is therefore further arranged to choose, from all the identified elements, the set of elements that provides the most information about the position on the surface (step F). This set of elements is, but need not be, continuous. The elements in the set of elements correspond in this example to a raster point matrix with raster points fitted to the image, but this is not a requirement. In other words, the purpose is to select the elements with associated value probabilities for each element value which maximise an information measure for the recorded image. For this purpose, an entropy is calculated for each of the identified elements. Thereafter the 8x8 elements are chosen that give the smallest entropy sum, which corresponds to the maximum information measure for the recorded image. If the value probabilities for the elements are normalised so that

$$\sum_i P_{2,i} = 1,$$

the entropy H for an element is calculated according to the following formula:

$$H = - \sum_i P_{2,i} \log_2(P_{2,i})$$

where $P_{2,i}$ is the value probability of the element for the element value i ($i=0, 1, 2, 3$) and where \log_2 is the two-logarithm. The entropy for an element is thus maximal when its value probabilities are equally high and minimal when all except one of the value probabilities are zero. An alternative to choosing 8x8 elements by means of entropy calculations is instead to use the highest value probability for each element as an information value. In this case, the continuous 8x8 elements are selected which maximise an information measure that consists of the sum of the information values for the 8x8 elements.

The coding pattern used in this example codes, as mentioned, two coordinates for a point on the surface 4. These coordinates are separately decodable. Therefore they can be called data in two dimensions. Each mark in the coding pattern codes more specifically a first bit which is used to decode the first coordinate and a second bit which is used to decode the second coordinate.

In the decoding of the coding pattern in the recorded image, each possible element value "0"- "3" for an element is therefore converted into a first and a second decoding value which in this example thus are binary. The device is thus arranged to convert, for each of the 8x8 elements in the set of elements, the element values "0"- "3" into the four different bit combinations (0, 1), (0, 0), (1, 0) and (1, 1). The bit combinations have the value probabilities belonging to the element values, for each element, see the continuation of the previous number example in Table 33 in Fig. 7a. In the bit combinations, the first bit, i.e. the first decoding value, refers to the first dimension and the second bit, i.e. the second decoding value, to the second dimension. The value probability P_2 for the corresponding element value is associated with the first and second decoding values. The set of elements can thus be used to create a first set of first decoding values with associated value probabilities for the first dimension, and a second set of second

decoding values with associated value probabilities for the second dimension (step G). Table 33 describes an element in the set of elements. The Tables 33' and 33" contain the corresponding first decoding values in the first set with associated value probabilities and respectively the second decoding values in the second set with associated value probabilities. Each of the first and the second decoding values is, as is evident from that stated above, either a zero or a one.

10 The device is arranged to associate for each element in the set of elements each of the different possible first decoding values in the first set with one value probability, and each of the different possible second decoding values in the second set with one value probability. Since the possible first and second decoding values in this example are zero and one, the above results in one value probability for the decoding value zero and one for the decoding value one in the first and second sets for each element in the set of elements. In the following, the value probability for the decoding value zero is called zero probability and the value probability for the decoding value one is called one probability.

Referring to Table 33', in this example, the above is carried out for each of the elements in the set of elements by comparing the value probabilities in the first set that correspond to the first decoding value being a zero. Then the highest value probability is chosen as zero probability and is saved in a first matrix 34. In the same way, the value probabilities in the first set that correspond to the first decoding value being one, are compared. Then the highest value probability is chosen as one probability and is also saved in the first matrix 34. Referring to Table 33", the above procedure is subsequently repeated for the value probabilities in the second set, the second decoding values and a second matrix 35. The first and the second sets are thus used to create a first and second matrix with zero and one proba-

bilities (step H). The result is illustrated in the continuation of the number example in Fig. 7b. Alternatively, a first and a second matrix with zero and one probabilities for the 8x8 elements in the set of elements are created by the value probabilities in the first set that correspond to the first decoding value being zero being added, the sum being stored as the zero probability, and by the value probabilities in the first set that correspond to the first number being one being added, the sum being stored as the one probability. The procedure is then repeated for the value probabilities in the second set and the second decoding values.

Thus the 8x8 elements in the set of elements now correspond to two matrices 34 and 35, each with 8x8 matrix elements, where each of the matrix elements contains one zero probability and one one probability. By means of these first and second matrices, coordinates can be determined for the position.

An alternative to choosing the set of elements after the determination of the value probabilities for all elements in the recorded image is to wait until matrices corresponding to the matrices 34 and 35 have been determined for all the identified elements. In this case, 8x8 matrix elements in each matrix can then be selected based on the corresponding zero and one probabilities. One way of doing this is to select 8x8 matrix elements in which one of the zero and one probabilities is high and the other low. In this case, the matrix elements corresponding to the same elements need not be selected for determination of both coordinates, the calculations proceeding with different corresponding elements for the two matrices.

In this example the position code is in the first dimension based on a first cyclic main number sequence. This gives a condition for the relation between the element values of the elements. The first cyclic main number sequence has the property that the place therein for each

partial sequence of a predetermined length is unambiguously determined. In this example the predetermined length is 6. If thus 6 succeeding numbers are taken in an arbitrary place in the first cyclic main number sequence, these six numbers occur only once in the first main number sequence in this succession. The property also applies if the end of the first main number sequence is connected to the beginning of the first main number sequence. Therefore, the first main number sequence is called cyclic. In this example a binary main number sequence is used. If the place for a partial sequence with six numbers is to be unambiguously determined, the first main number sequence can then maximally have the length $2^6=64$ and the partial sequences of the length 6 can have places 0-63 in the first main number sequence. If, however, a first main number sequence of the length 63 is chosen, it is possible, as will be evident from the following, to provide improved error correction properties. In the following, it will thus be assumed that the length of the first main number sequence is 63 and that it thus defines unique places in the range 0-62.

Fig. 8 shows an example of a first cyclic main number sequence that can be used in connection with the position coding. The partial sequence 0,0,0,0,0,0 has, for instance, the unambiguous place 0, the partial sequence 1,1,1,1,1,0 the unambiguous place 9 and the partial sequence 1,1,1,0,1,0 the unambiguous place 11 in the first main number sequence. For determining a position on the surface, 6x6 elements must be identified in the recorded image. As discussed above, however, use is made of 8x8 elements for a position determination and the reason for this will be evident from the following. As stated above, the first cyclic main number sequence, on which the position code is based in the first dimension, has the property that it contains merely mutually unique partial sequences of the length 6. Consequently, also the place in the first cyclic main number sequence for each

partial sequence of the length 8 is unambiguously determined. This fact is utilised in the determination of the coordinates for the position on the surface.

The device is arranged to match each of the unique
5 partial sequences of the length 8 in the first cyclic
main number sequence with each of the columns in the
first matrix 34 (step I). The method is illustrated in
Fig. 9. The Figure shows an example of a binary partial
sequence 36 of the length 8 and a column 37 in the first
10 matrix 34 (Fig. 7b), said column having matrix elements
which each contain a zero probability and a one probability
corresponding to the first decoding value being
zero and one respectively. For each matrix element, one
of the zero and one probabilities is selected depending
15 on the corresponding number in the partial sequence 36.
The first number in the partial sequence 36 is, for
instance, zero, which means that the zero probability is
selected for the first matrix element in the column 37.
The second number in the partial sequence is one, which
20 means that the one probability is selected for the second
matrix element in the column 37. For each partial
sequence in the first main number sequence, for each
column in the first matrix 34, the device is in addition
arranged to calculate a first sequence probability (step
25 J) by multiplication of the correspondingly selected zero
and the one probabilities for the matrix elements. In
Fig. 9, the first sequence probability 38 corresponding
to the partial sequence 36 and the column 37 has been
calculated. After this operation, there will thus be 63
30 first sequence probabilities with a respective associated
unique sequence value for each column in the first matrix
34. These sequence values are defined by the places of
the corresponding partial sequences in the first cyclic
main number sequence. The device is arranged to select
35 for each column the highest first sequence probability
and the corresponding sequence value and save these.

The position code in the second dimension is here based on a second cyclic main number sequence which in this example has the same properties as the first cyclic main number sequence.

5 The device is further arranged to match, in a manner corresponding to that above, each of the unique partial sequences of the length 8 in the second cyclic main number sequence with each of the rows in the second matrix 35. The rows in the matrix 35 have, just like the columns 10 in the matrix 34, matrix elements which each contain one zero probability and one probability corresponding to the second decoding value being zero and one respectively. For each matrix element, one of the zero and one probabilities is selected depending on the corresponding 15 number in a partial sequence in the second cyclic main number sequence. For each partial sequence in the second main number sequence, for each row in the second matrix 35, the device is further arranged to calculate a second sequence probability (step J) by multiplication of the 20 correspondingly selected zero and one probabilities for the matrix elements. After this operation, there will thus be 63 second sequence probabilities with a respective associated unique sequence value for each column in the second matrix 35. These sequence values are defined 25 by the places of the corresponding partial sequences in the second cyclic main number sequence. The device is further arranged to select for each row the highest second sequence probability and the corresponding sequence value and save these.

30 The position code used in this example is based on use of different rotations or circular shifts of the cyclic main number sequences. In order to code positions in, for instance, the x direction, the first main number sequence is printed or arranged in some other manner rotated or circularly shifted in different ways in 35 columns across the surface, i.e. in the y direction orthogonally to the direction in which positions are to

be coded, from above and down. The main number sequence may be printed repeatedly in the same column, which is necessary if more positions than what corresponds to the length of the main number sequence are to be coded in the y direction. The same rotation of the main number sequence is then used in all repetitions. This means that different rotations can be used in different columns.

Each pair of adjoining columns defines a difference number D. The difference number D is given by the difference between the places in the main number sequence for the first partial sequence in each column. If instead the difference between the places for the partial sequences is taken one step down in the columns, the result will be the same as the places will be offset in the same way. The difference number D will thus always be the same independently of at what "height" in the columns the places of the partial sequences in the main number sequence are compared. For each pair of columns, the difference number D is thus constant in the y direction. The difference numbers between adjoining columns form a set of difference numbers that can be used to obtain a coordinate for a position on the surface in the first dimension.

The position code in a second direction, for instance in the y direction in this case, can be based on the same principle as the position code in the first dimension. The second main number sequence is then arranged with different circular shifts in rows on the surface, i.e. in the x direction, from the left to the right. Difference numbers are defined between adjoining rows and these difference numbers form a set of difference numbers that can be used to obtain a coordinate for a position on the surface in the second dimension.

Thus the position code consists of one partial position code for the first direction and one partial position code for the second direction.

As is evident from that stated above, the partial sequences are not written with their explicit values, but with a graphical coding. In the graphical coding, marks define a superposing of the partial position codes.

5 Since the position code is based on main number sequences which are arranged in predetermined directions on the surface, the marks must be decoded in these directions for the position determination to be correct. The correct decoding directions are, as mentioned above, from
10 above and down and from the left to the right.

The device 1 can, when recording an image, be held rotated in different locations relative to the surface and the position code. There are four possible recording rotations which are shown as arrows 40 in Fig. 10. The
15 recorded image of the position code does not in itself reveal the relative rotation between the position code and the device since the position code has essentially the same appearance if it is rotated through 0, 90, 180 or 270 degrees. When the position code has been rotated,
20 the direction of the displacement of each mark in relation to the raster point with which it is associated will, however, be changed. This results in turn in the bit combination (first decoding value, second decoding value) which codes the displacement of the mark being
25 changed. With the "correct" rotation of the position code, the marks are arranged in the correct decoding directions from above and down in the columns as well as from the left to the right in the rows. If the correct rotation of the position is zero, the following applies
30 to the incorrect rotations:

▪ 90 degrees clockwise: the columns with marks in the "correct" rotation, which marks are arranged from above and down, will be rows with marks arranged from the right to the left, i.e. in
35 the incorrect decoding direction, and the rows with marks in the "correct" rotation, which marks are arranged from the left to the right,

will be columns with marks arranged from above and down, i.e. in the correct decoding direction.

- 5 ▪ 180 degrees: the columns with marks in the "correct" rotation will be columns with marks arranged from below and up, i.e. in the incorrect decoding direction, and the rows with marks in the "correct" rotation will be rows with marks arranged from the right to the left, i.e. in the incorrect decoding direction.
- 10 ▪ 270 degrees clockwise: the columns with marks in the "correct" rotation will be rows with marks arranged from the left to the right, i.e. in the correct decoding direction, and the rows with marks in the "correct" rotation will be columns with marks arranged from below and up, i.e. in the incorrect direction.
- 15

If the marks in the columns and the rows are arranged in the incorrect decoding direction, the zero and one probabilities for each element will be inverted when decoded.

Therefore the device is arranged to test, as will be described below, different rotations of the partial area of the position code in the recorded image. The operation that was carried out on the first and the second matrix 34 and 35, respectively, i.e. the matching of the partial sequences in the cyclic main number sequences against columns and rows respectively in the matrices (step I), the calculation of sequence probabilities (step J), and the selection of the highest sequence probabilities with corresponding sequence values for the columns and the rows respectively, is carried out also on the first and the second matrix 34 and 35 rotated through 180 degrees and "inverted", which matrices in Fig. 7c are designated 34' and 35' respectively. These rotated, inverted matrices 34' and 35' correspond to an inverted version of the partial area of the position code in the recorded

image. The reason for this is explained in Fig. 11 which shows an example of a partial area of a position code in a recorded image. In the Figure, only 9 marks are used for the sake of simplicity which are each associated with one raster point for the illustration. The position code 45 is the one recorded in the image. The position code 45' is the same position code inverted. The matrices 46 and 47 correspond to the matrices 34 and 35 respectively for the position code 45 turned the right way round, and the matrices 48 and 49 correspond to the matrices 34' and 35' respectively for the inverted position code 45'. If the matrices 48 and 49 for the inverted position code are rotated through 180 degrees and inverted, the matrices 46 and 47 will be obtained for the position code turned the right way around. By inversion is in this context meant that the zero and one probabilities in each matrix element change places.

After the above procedure, there is a highest sequence probability with a corresponding sequence value for each column in the matrices 34 and 34', and for each row in the matrices 35 and 35'. For each of the matrices 34, 34', 35 and 35', the device is then arranged to calculate a rotation probability (step K) by multiplication of the corresponding highest sequence probabilities. Based on the sequence values corresponding to the highest sequence probabilities for that of the matrices 34 and 34' which corresponds to the highest rotation probability, and the sequence values corresponding to the highest sequence probabilities for that of the matrices 35 and 35' which corresponds to the highest rotation probability, coordinates for the position can be calculated.

As described above, it is not necessary to examine all four rotations. This is simply explained by means of an example. Now assume that the partial area of a position code in an image that is recorded is the one (45) shown in Fig. 11. Further assume that the "correct" rota-

tion of the position code is rotated through 90 degrees clockwise relative to the recorded one. According to the above description, where the correct rotation is assumed to correspond to a rotation through 0 degrees, this means
5 that the position code 45 in the recorded image is rotated through 270 degrees clockwise relative to the "correct" rotation. Consequently, the position code 45' is rotated through 90 degrees clockwise relative to the "correct" rotation. In the manner described above, the
10 position codes 45, 45' are now decoded in Fig. 11. The columns with marks in the "correct" rotation through 0 degrees are, as described above, arranged in the correct decoding direction in the position code 45. The correct direction causes the sequence probabilities, and consequently the rotation probability, corresponding to
15 these rows, to be high. The rows with marks in the correct rotation are, as described above, columns arranged in the incorrect decoding direction in the position code 45. The incorrect direction combined with the inversion
20 causes the value probabilities, and consequently the rotation probability, corresponding to these columns, to be low. The relationship will be the opposite for the position code 45'. The columns with marks in the correct rotation through 0 degrees are, as described above, rows
25 arranged in the incorrect decoding direction in the position code 45'. The incorrect direction causes the sequence probabilities, and consequently the rotation probability, corresponding to these rows, to be low. The rows with marks in the correct rotation are, as described
30 above, columns arranged in the correct decoding direction in the position code 45'. The correct direction causes the sequence probabilities, and consequently the rotation probability, corresponding to these columns, to be high.

When recording the "correct" rotation of the position code, columns and the rows will, as mentioned above,
35 extend in the "correct" direction in the image. This means for the example in Fig. 7 that the rotation proba-

bilities for the matrices 34 and 35 will both be higher than the rotation probabilities for the matrices 34' and 35'. This is an indication that the "correct" rotation of the position code has been recorded. Thus, a first coordinate can be calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 34, and a second coordinate can be calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 35.

When recording the position code rotated through 180 degrees in relation to the "correct" rotation, the columns and the rows will extend in the "incorrect" direction in the image. This means for example in Fig. 7 that the rotation probabilities for the matrices 34' and 35' will both be higher than the rotation probabilities for the matrices 34 and 35. This is an indication that the position code has been recorded in the rotation through 180 degrees in relation to the "correct" rotation. Thus, a first coordinate can be calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 34', and a second coordinate can be calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 35'.

Recording of the position code rotated through 90 or 270 degrees clockwise in relation to the "correct" rotation is indicated by the highest rotation probabilities not belonging to the same rotation. If it is assumed that the matrices 34 and 35 in Fig. 7 originate from a position code which is rotated through 90 degrees clockwise in relation to the correct direction, the rotation probability for the matrix 34 will be higher than the rotation probability for the matrix 34', and the rotation probability for the matrix 35 will be lower than the rotation probability for the matrix 35'. In this case, the second coordinate is calculated based on the sequence values corresponding to the highest sequence probabilities for

the matrix 34, and the first coordinate is calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 35'. If it is assumed instead that the matrices 34 and 35 in Fig. 6 originate from a position code which is rotated through 270 degrees clockwise in relation to the correct direction, the second coordinate is instead calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 34', and the first coordinate is calculated based on the sequence values corresponding to the highest sequence probabilities for the matrix 35.

What allows the detection of the rotation of the position coding in the recorded image thus is the fact that the rotation probability for a matrix is changed when the matrix is rotated through 90, 180 or 270 degrees. If the rotation of the position code is different from zero, i.e. if the rotation of the position code in the recorded image is incorrect, the rotation probability as stated above will be low. This depends on the fact that the unique partial sequences of the length 8 in the cyclic main number sequences do not occur inverted or reverse in the main number sequences. If such a condition should be satisfied for the main number sequences for partial sequences of the length 6, it would mean that the main number sequences would be reduced significantly, which in turn would imply that fewer positions could be coded. This is thus one reason why 8x8 elements are used for the position determination although only 6x6 are theoretically required.

The same basic principles as the ones used in the rotation detection can be used for error correction. For instance, the main number sequence can be selected so that partial sequences of a predetermined length, which is longer than the one required for position determination, do not occur with one bit inverted in the main number sequence. Then, if all bits except one in such a

longer partial sequence can be detected with certainty, the incorrect bit can be corrected. This is another reason why 8x8 elements are used for the position determination although only 6x6 are theoretically required.

5 Thus, by an intelligent selection of the main number sequence, the error detection and error correction properties of the coding pattern can be considerably improved.

10 The property of the cyclic main number sequences that partial sequences of the length 8 do not occur inverted or reverse can, however, not be provided for a 64 bit long main number sequence, which is the reason why the length of the main number sequences has instead been selected to be 63.

15 In decoding, redundant information is thus used to obtain error correction properties. In the example described above, 8x8 elements are used in the decoding, although the position information can be extracted based on 6x6 raster points, i.e. there is 56 bit redundant
20 information $[(8^2 - 6^2) \times 2]$ for determining the position. In decoding, information in the current image is matched, by columns and by rows, with the different partial sequences that may occur in the position code, while using the value probabilities belonging to the current image. The
25 combination of redundant information, probabilities and a known condition for the relation between the values of the elements gives good insensitivity to interference in the current image. The value of each individual mark thus decreases in importance since the value of the individual
30 mark must correspond to the other values in that of the partial sequences which gives the highest sequence probability.

35 If the need for error correction is more limited, the device can alternatively be arranged to directly select, for each of the columns in the first matrix, and for each of the rows in the second matrix, a sequence,

and thus a sequence value, corresponding to the highest of the zero and one probability for each element.

When the rotation 40' of the recorded position code in relation to the "correct" rotation has been established, the first and second coordinate of the position can thus be determined (step L). This is carried out as described above, based on sequence values which in Fig. 10 are designated Sx_1-Sx_8 (41) for the first coordinate and Sy_1-Sy_8 (42) for the second coordinate.

The device is arranged to calculate for the sequence values Sx_1-Sx_8 and Sy_1-Sy_8 differences between adjacent sequence values, which results in two sets, 43 and 44, of seven difference numbers Dx_1-Dx_7 and Dy_1-Dy_7 each. These difference numbers are then used to generate a first coordinate and a second coordinate.

For the calculation of the first coordinate, however, only six of the sequence values Sx_1-Sx_8 , i.e. five of the difference numbers Dx_1-Dx_7 , are necessary as described above. According to this example, the sequence values Sx_2-Sx_7 and thus the difference numbers Dx_2-Dx_6 are used. The same applies to the second coordinate that is then calculated from the sequence values Sy_2-Sy_7 and thus the difference numbers Dy_2-Dy_6 . Alternatively, only six sequence values are determined for each direction, Sx_2-Sx_7 and Sy_2-Sy_7 .

The conversion from difference numbers to coordinates can be carried out in many ways, for example in the way that is described in Applicant's applications WO 01/26033 and SE 0103589-8 which are herewith incorporated by reference.

In the example described above, 8x8 elements have been identified, for data decoding, in a recorded image. However, it may sometimes happen that it is not possible to identify so many elements. "Empty" additional elements are then added to the elements that can be identified in the image to obtain a total of 8x8 elements. As described

earlier, the value probabilities for an "empty" element are all equal.

Fig. 12 shows a sheet of paper which has a surface 50 that is provided with an alternative position code 51 which consists of marks 52 and which for the sake of clarity is greatly enlarged. In this case, the value of the marks 52 is defined by their size. This type of position code is described in Patent Publication WO 00/79383, which is herewith incorporated by reference.

In this case, the device is arranged, just as described above, to record an image of a partial area of the position code, to identify a plurality of marks in the image, and to fit a raster to the image so that each of the marks is associated with a raster point. Like in the case with the above position code, the marks associated with a raster point constitute an element belonging to the raster point. Here are two possible values for each mark. The small mark 53 corresponds to the value zero and the large mark 54 corresponds to the value one, and there is an ideal size of the small and large marks.

The identified marks are usually not of an ideal size. In many cases, it can therefore be difficult to unambiguously determine a value for each mark 52. The device is therefore arranged as above to calculate, for each identified mark, an associated value probability for each value "0" and "1" that the mark defines this value.

The size of the marks 52 may be assumed to be normally distributed around the ideal sizes, which means that the value probabilities $P(r)$ can be calculated by the formula $P(r) = k \exp(-(R_i - r)^2/v)$, where k = a constant, R_i = ideal size, r = size of a mark and v = a constant, in this example the variance of the size. R_i and r can be, for instance, areas or radii. The variance can be determined empirically.

Thus, for each mark, two value probabilities can be calculated. The case in which there is no mark associated with a raster point, i.e. the associated element contains

zero marks, is dealt with as if there were two marks of the ideal size, one with the value "0" and one with the value "1", associated with the raster point.

5 If there is more than one mark, for example three, associated with a raster point, i.e. three marks in the associated element, then there are a total of 3×2 value probabilities for the raster point or element. The device is therefore arranged as above to determine, for each raster point or element and for each value, value proba-
10 bilities that the marks associated with the raster point together define this value. For each element, value probabilities are thus calculated that the element defines each of the values, and therefore the values "0" and "1" can also in this case be called element values.

15 The value probabilities for an element can be determined, as above, by the value probabilities for the marks in the element being compared, the highest value probability being selected for each element value. Alternatively, the value probabilities for the element can be
20 weighted sums of the value probabilities for the element values for the marks in the element. In the case of this position code, the value probabilities for the element can, of course, also be determined in other ways than those mentioned above.

25 Also in this case, the value probabilities for a mark and an element are the same if the element only contains that mark.

Like with the position code described by way of introduction, the value probabilities for the elements
30 are then used to determine a position on the surface in a manner corresponding to that described in detail above.

One alternative as regards the latter position code is to let the value probabilities to be a function of the total dark area corresponding to a raster point. This
35 alternative could be useful if there is only one mark associated with each raster point. Sometimes it may in fact happen that for some reason a mark in a recorded

image of the position code is not a completely continuous area. Then there is a risk that the mark appears to be split and thus, is perceived by the device as several marks.

5 In the above described examples, probabilities have been multiplied on several different occasions to obtain various results. It can be pointed out that in cases in which the probabilities that are to be multiplied are described by exponential functions, logarithms can be
10 used, so that the results are obtained instead by summing up exponents according to the following formula.

$$\ln(\exp(a) \cdot \exp(b)) = \ln(\exp(a)) + \ln(\exp(b)) = a + b$$

Figs 13a and b show two additional types of codes that can be used in connection with the present invention. The code 55 in Fig. 13a consists of marks 56 in
15 the form of small lines. The values of the marks 56 depend upon the inclination of the lines. The mark 57 corresponds to the value zero and the mark 58 corresponds to the value one. This type of code is described in the application US-A-5,245,165, which is herewith incorporated by reference. The code 59 in Fig. 13b consists of a
20 square grid 60, with triangles 61 being placed in the squares. The square 62 has the value zero and the square 63 has the value one.

25 Another code that can be used in connection with the present invention consists of marks that have two different ideal shapes, a first and a second ideal shape, with the density of the marks on a surface providing information about the position. In this case, the density varies
30 in two dimensions, the density of marks with a first ideal shape varying in a first dimension and the density of marks with a second ideal shape varying in a second dimension.

There are a plurality of other codes that can be
35 used in connection with the present invention, the variants described above only being regarded as examples.

When an image of a partial area of a position code has been recorded, the marks are identified by dark continuous areas in the image being searched out. It is, however, the case that the dark continuous areas in the image are not necessarily marks in the position code. There are sometimes impurities, for instance in the form of dust, on the surface on which the position code is printed. These impurities cause noise marks in the recorded image, which noise marks may then by mistake be identified as marks in the position code. Also sensor noise may cause noise marks in the recorded image. Noise marks in the recorded image may also originate from a defect on one of the components in the device, for instance damaged pixels in the sensor.

In the first case, in which the values of the marks are determined based on their distance from the ideal locations, there is however a factor that prevents any noise marks from having an effect on the result of the position determination. If a good fit of a raster has been made for the recorded image, the noise marks will be located at a greater distance from the ideal locations than the marks of the position code. In the second case, there is another factor that prevents the noise marks from having an effect on the result. The noise marks are usually much smaller than the marks of the position code. When determining the value probabilities for an element, the value probabilities for the noise marks will thus be of less importance since they are much lower than those for the marks of the position code.

A person skilled in the art will recognise that the above examples can be varied in a number of ways without departing from the concept of the invention.

There are two different parameters for the marks in the position codes that have been discussed in this application, namely the location of the marks and their shape/size. Depending upon which position code is used, one of the parameters will indicate the value of the

marks. The other parameter can then suitably be used to calculate a probability of the identified mark being a mark in the position code.

5 In the case of the position code in which the value of the marks is defined by their location in relation to a raster, for example, the area of the marks can correspond to a mark probability, which indicates the probability that a current mark is really a mark in the position code. The value probabilities for each mark can then
10 be multiplied by its mark probability before the raster point probabilities are calculated. An alternative to this method is that a form of area filter is used in the device to remove the noise marks completely at an early stage. This filter acts in such a way that all marks that
15 have an area that lies between two limit values are identified as marks in the position code, while all marks outside the limit values are rejected.

In the case of the position code in which the value of the marks is defined by their shape/size, for example,
20 the location of the marks in relation to a raster can instead indicate the probability that a mark is a mark in the position code.

It would of course also be possible to use the invention in connection with position determination in
25 a single dimension. In the case of the position code discussed by way of introduction, this would mean that one of said first and second sets would be used to determine in the manner described above a first or a second coordinate for the position.

30 The invention is not limited to use in connection with position codes that are based on binary number bases. Of course also other number bases can be used to express the cyclic main number sequences, as well as the element values in the first and the second decoding
35 values.

Moreover, the invention is not limited to use in connection with position codes where the elements assume

two or four element values. In one alternative, the elements may instead assume eight element values. Each element value may then be converted into a first, a second and a third decoding value for each of three dimensions.

5 Consequently also a third set and a third matrix may be created for a third dimension. This could be used, for instance, to determine a position in three dimensions.

The device and the method according to the present invention are not limited to use in connection with coding of positions, but can also be used in other situations, for example when decoding data stored in the form of a code on a base, as described in Patent Application
10 WO 01/71653, which has been assigned to the present applicant and which is herewith incorporated by reference.
15

CLAIMS

1. A method for data decoding, comprising
5 decoding data stored in a partial area of a coding pattern on a surface, based on a recorded image of the partial area, said coding pattern containing elements which each have at least two possible decoding values, c h a r a c t e r i s e d by
10 identifying in the image a plurality of said elements,
calculating, for each identified element, an associated value probability for each possible decoding value that the element has this decoding value, and
15 performing the decoding of data based on the decoding values and the corresponding value probabilities.
2. A method as claimed in claim 1, wherein the decoding of data comprises determining a coordinate for a point on the surface.
- 20 3. A process as claimed in claim 1, wherein the decoding of data comprises determining two coordinates for a point on the surface.
4. A method as claimed in any one of claims 1-3, wherein the decoding of data comprises decoding at least
25 a first set of decoding values for a predetermined number of the identified elements.
5. A method as claimed in claim 4, comprising calculating, by means of the value probabilities for the first set of decoding values, a sequence probability for
30 each of a plurality of permissible combinations of decoding values, each sequence probability indicating the probability of a sequence of elements in the recorded partial area of the image having said combination of decoding values.
- 35 6. A method as claimed in claim 4, further comprising selecting, for each of the elements corresponding to the first set of decoding values, the decoding value

which has the highest associated value probability, and carrying out the decoding of data based on the selected decoding values.

7. A method as claimed in claim 4, further comprising selecting, for each of the elements corresponding to the first set of decoding values, one of the possible decoding values based on a condition, given by the coding pattern, for the relation between the decoding values of the elements.

8. A method as claimed in claim 7, wherein said condition indicates permissible combinations of the decoding values for the elements corresponding to the first set.

9. A method as claimed in claim 5 or 8, wherein the permissible combinations are determined by a cyclic main number sequence, which contains only mutually unique partial sequences of a predetermined length, each partial sequence corresponding to one of the permissible combinations.

10. A method as claimed in claim 9, wherein the partial sequences and the cyclic main number sequence are such that no partial sequence is present in the cyclic main number sequence in inverted and reversed form.

11. A method as claimed in claim 8, comprising carrying out the decoding of data based on sequence probabilities, a sequence probability for a sequence of elements being defined based on the value probabilities for the decoding values for the sequence that correspond to one of the permissible combinations.

12. A method as claimed in claim 11, comprising carrying out the decoding of data based on the decoding values for the sequence that give the highest sequence probability.

13. A method as claimed in any one of claims 4-12, wherein each element has at least two possible decoding values for each of two separately decodable dimensions of data, the decoding values of the first set consisting of

the possible decoding values for the first dimension of data.

14. A method as claimed in claim 13, wherein each element has at least four possible element values, which
5 correspond to different combinations of a possible decoding value of the first dimension and a possible decoding value of the second dimension, further comprising calculating, for each identified element, an associated value probability for each possible element value that the ele-
10 ment has this element value.

15. A method as claimed 14, further comprising dividing each of the possible element values for the elements corresponding to the first set into a first possible decoding value for the first dimension and a
15 second possible decoding value for the second dimension and associating with each of these decoding values the value probability of the element value.

16. A method as claimed in claim 15, wherein the division of the possible element values takes place by
20 the element value being expressed as two numbers in a number base which is smaller than the number base in which the element value is expressed.

17. A method as claimed in claim 15 or 16, further comprising assigning, if the division of two of the pos-
25 sible element values for an element results in two identical possible decoding values for one dimension of data, the possible decoding value the highest of the value probabilities assigned to these element values.

18. A method as claimed in any one of claims 4-17,
30 wherein the decoding of data further comprises decoding a second set of decoding values for a predetermined number of the identified elements.

19. A method as claimed in claim 18, wherein the decoding values in the second set consist of the possible
35 decoding values for the second dimension of data, further comprising the step of assigning each decoding value in the second set a value probability which indicates the

probability of the corresponding element having this decoding value.

20. A method as claimed in claim 18 or 19, wherein the decoding values and their associated value probabilities are determined in the same manner as the decoding values for the first set, and the decoding of the second set of decoding values is carried out in the same way as the decoding of the first set of decoding values.

21. A method as claimed in claim 5 or 11, comprising carrying out the decoding of data based on rotation probabilities, which correspond to different rotations of the recorded image and which are defined based on the sequence probabilities.

22. A method as claimed in any one of claims 1-3, comprising carrying out the decoding of data based on rotation probabilities, which correspond to different rotations of the recorded image and which are defined based on the value probabilities associated to the decoding values of the identified elements.

23. A method as claimed in claim 21 or 22, comprising carrying out the decoding of data based on the rotation of the recorded image which corresponds to the highest rotation probability.

24. A method as claimed in any one of claims 1-12, wherein each element has at least two possible element values, which are identical with the possible decoding values of the element, and wherein each element value has an associated value probability which is identical with the value probability of the decoding value.

25. A method as claimed in claim 14 or 24, wherein each of the identified elements comprises at least one mark and the value probabilities of the element values are calculated based on the size of the marks in relation to a number of ideal sizes R_i of the marks.

26. A method as claimed in claim 25, wherein the value probabilities of the element values, for each of

the ideal sizes R_i , is a function of $\exp(-(R_i-r)^2/v)$ where r is the size of the mark and v is a constant.

27. A method as claimed in claim 14 or 24, wherein each of the identified elements comprises at least one mark, which is associatable with one reference point of a number of reference points in a reference system, and wherein the value probabilities of the element values are calculated based on the location of the marks in relation to the reference points with which they are associated.

28. A method as claimed in claim 27, wherein the value probabilities are defined by the distance (26) of the marks to each of a number of ideal locations belonging to the reference points with which they are associated.

29. A method as claimed in claim 28, wherein the value probabilities for each mark, for each of the distances d_i , are a function of $\exp(-(d_i)^2/v)$ where v is a constant.

30. A method as claimed in any one of claims 27-29, wherein the reference system is a raster and the reference points are raster points, which each consists of an intersection in the raster.

31. A method as claimed in claims 14 or 24 in combination with claim 4, wherein the elements corresponding to the first set are selected based on a maximising of an information measure for the first set, said information measure being defined based on the value probabilities for the element values of the elements corresponding to the first set.

32. A device for data decoding, comprising processing means for decoding of data which is stored in a partial area of a coding pattern on a surface, based on a recorded image of the partial area, which coding pattern contains elements, which each have at least two possible decoding values, characterised in that it is arranged to

identify in the image a plurality of said elements,

calculate for each identified element an associated value probability for each possible decoding value that the element defines this decoding value, and

5 carry out the decoding of data based on the decoding values and the corresponding value probabilities.

33. A device for data decoding as claimed in claim 32, said device being adapted to decode at least a first set of decoding values for a predetermined number of the identified elements.

10 34. A device for data decoding as claimed in claim 33, said device being adapted to calculate, by means of the value probabilities for the first set of decoding values, a sequence probability for each of a plurality of permissible combinations of decoding values, each
15 sequence probability indicating the probability that a sequence of elements in the partial area of the recorded image has said combination of decoding values.

35. A device for data decoding as claimed in claim 33 or 34, said device being adapted to select, for each
20 of the elements corresponding to the first set of decoding values, one of the possible decoding values based on a condition, given by the coding pattern, for the relation of the decoding values of the elements.

36. A device for data decoding as claimed in claim 32, adapted to carry out the decoding of data based on
25 rotation probabilities, which correspond to different rotations of the recorded image and which are defined based on the value probabilities associated to the decoding values of the identified elements.

30 37. A memory medium on which is stored a computer program with instructions for data decoding based on an image as claimed in any one of claims 1-31.

38. Use of probability calculations in data decoding based on an image of a coding pattern.

35

ABSTRACT

A method, a device, a memory medium on which is
5 stored a computer program, and use of probability calculations for data decoding are provided. The method comprises decoding data stored in a partial area of a coding pattern on a surface, based on a recorded image of the partial area. The coding pattern contains elements
10 which each have at least two possible decoding values. The method is characterised by identifying in the image a plurality of elements. The method further comprises calculating, for each identified element, an associated value probability for each possible decoding value that
15 the element has this decoding value. Additionally, the method comprises performing the decoding of data based on the decoding values and the corresponding value probabilities.

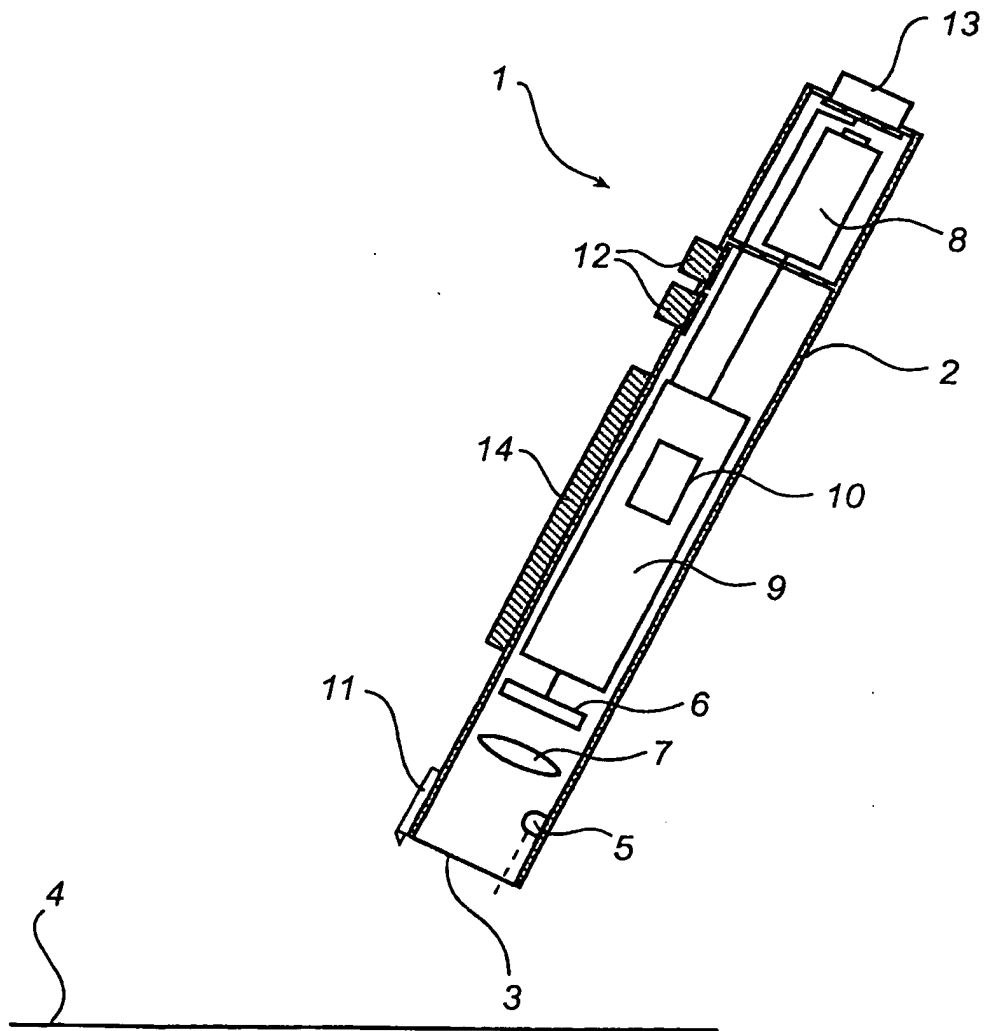


Fig. 1

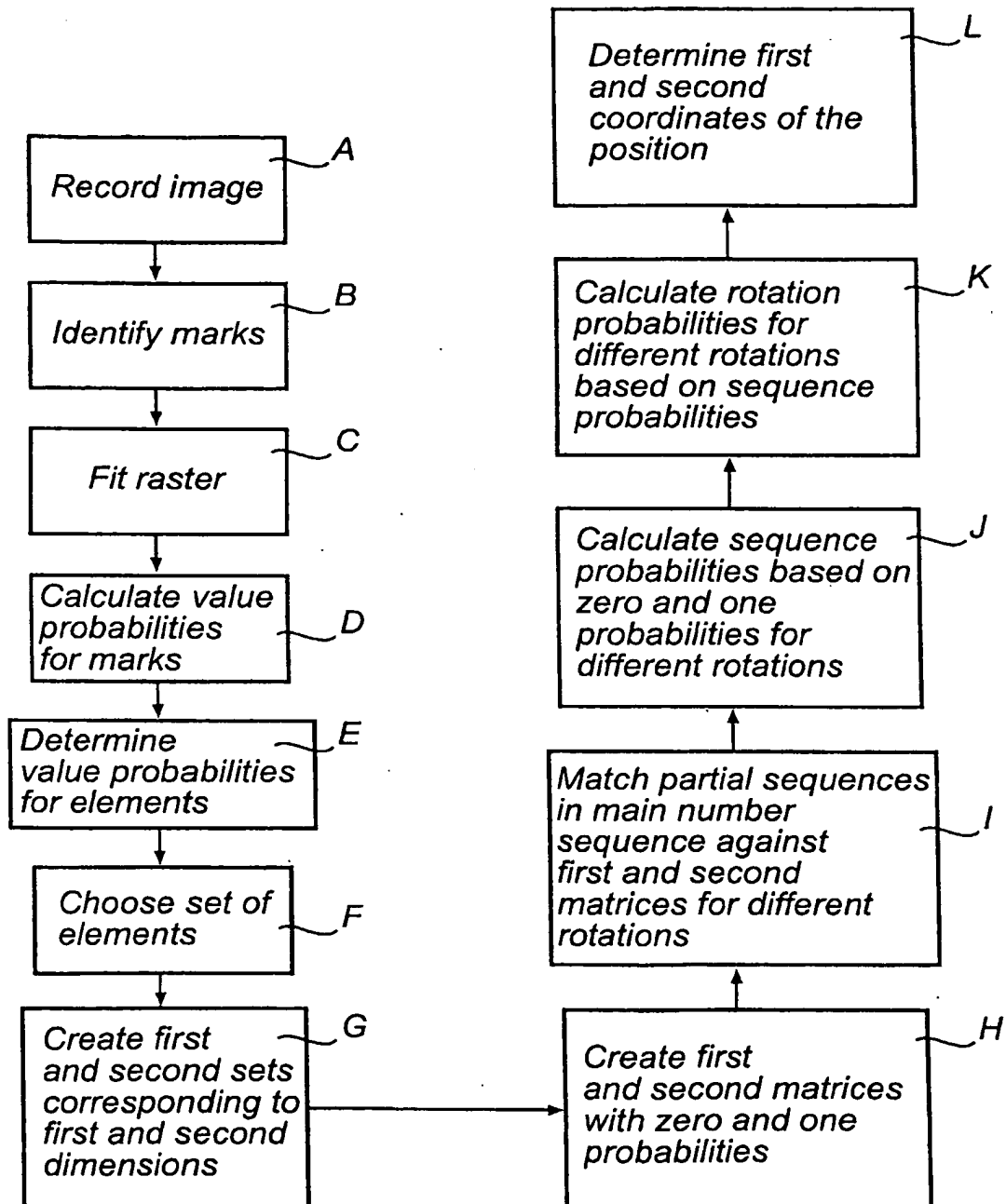


Fig. 2

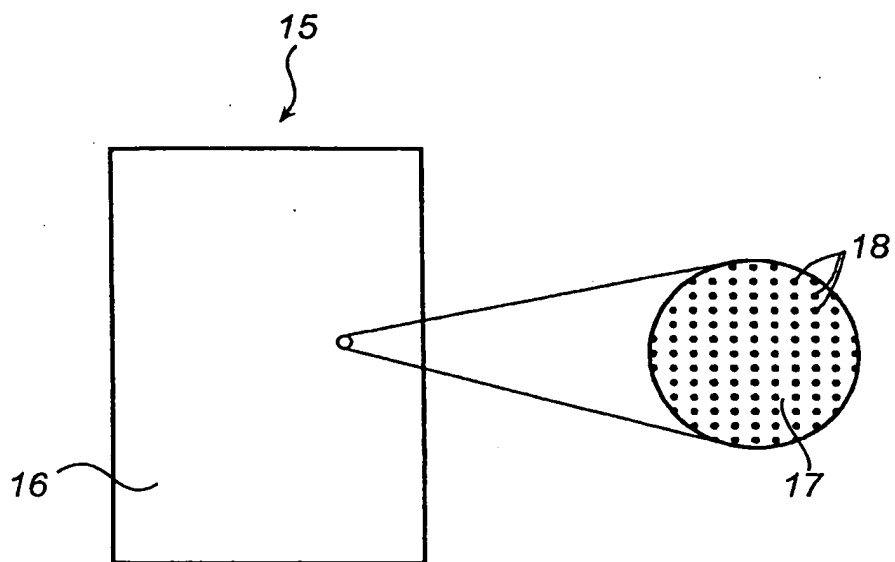


Fig. 3a

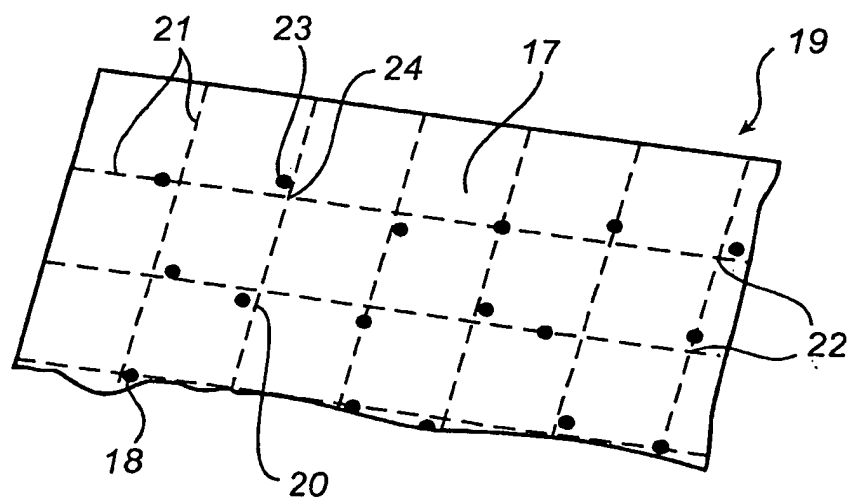


Fig. 3b

4/10

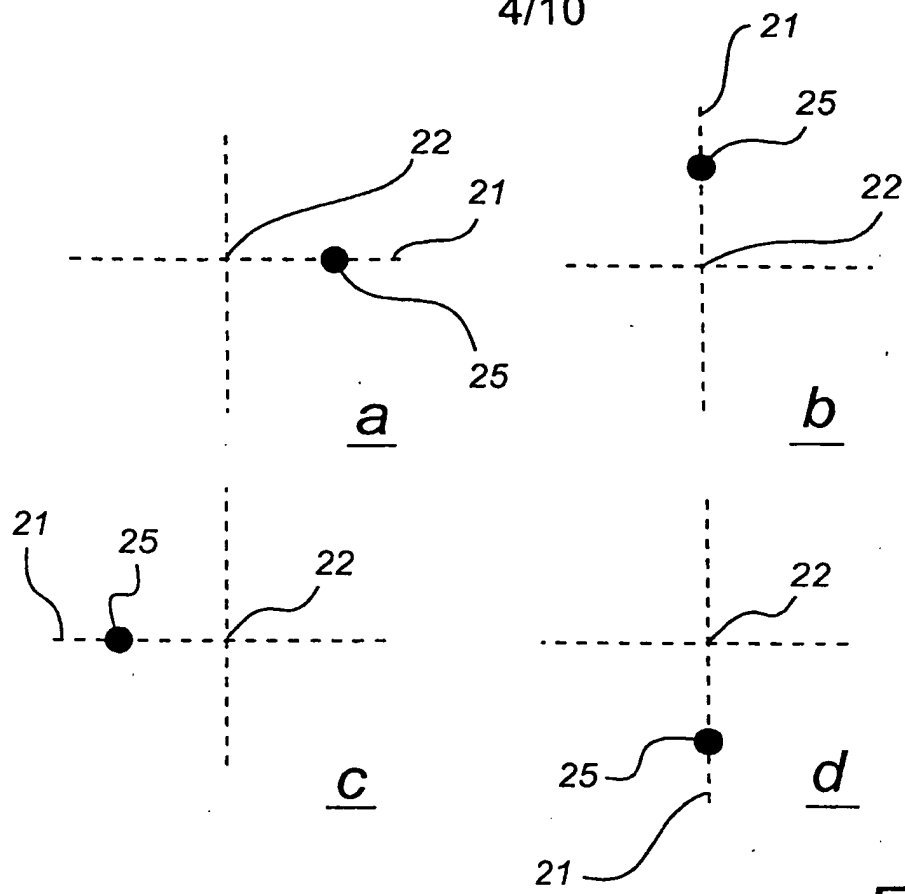


Fig. 4

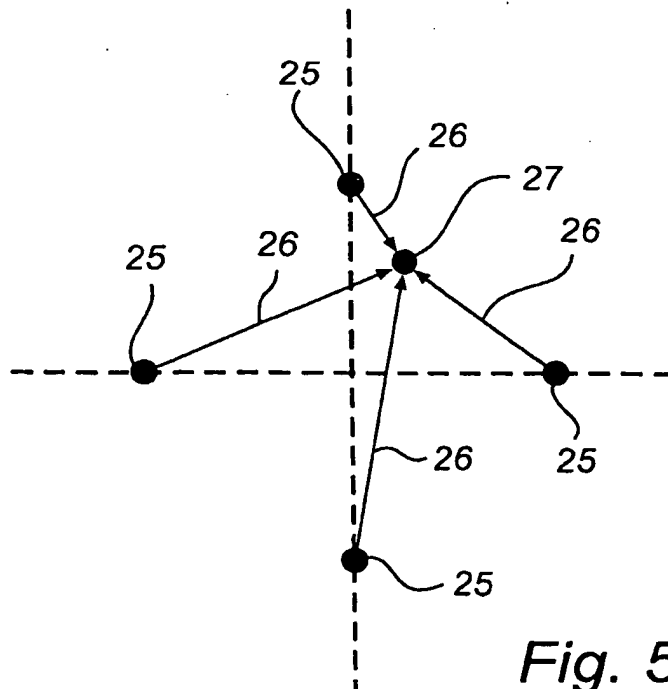


Fig. 5

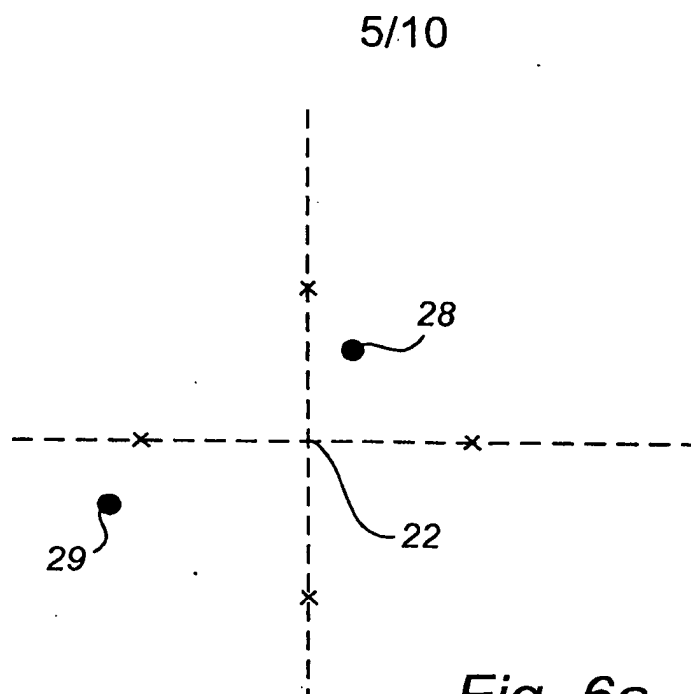


Fig. 6a

30	<table border="1"> <tr> <th>Value</th><th>P_1</th></tr> <tr> <td>"0"</td><td>0,26</td></tr> <tr> <td>"1"</td><td>0,45</td></tr> <tr> <td>"2"</td><td>0,16</td></tr> <tr> <td>"3"</td><td>0,13</td></tr> </table>	Value	P_1	"0"	0,26	"1"	0,45	"2"	0,16	"3"	0,13
Value	P_1										
"0"	0,26										
"1"	0,45										
"2"	0,16										
"3"	0,13										
31	<table border="1"> <tr> <th>Value</th><th>P_1</th></tr> <tr> <td>"0"</td><td>0,11</td></tr> <tr> <td>"1"</td><td>0,13</td></tr> <tr> <td>"2"</td><td>0,57</td></tr> <tr> <td>"3"</td><td>0,19</td></tr> </table>	Value	P_1	"0"	0,11	"1"	0,13	"2"	0,57	"3"	0,19
Value	P_1										
"0"	0,11										
"1"	0,13										
"2"	0,57										
"3"	0,19										

Fig. 6b

32	<table border="1"> <tr> <th>Element value</th><th>P_2</th></tr> <tr> <td>"0"</td><td>0,26</td></tr> <tr> <td>"1"</td><td>0,45</td></tr> <tr> <td>"2"</td><td>0,57</td></tr> <tr> <td>"3"</td><td>0,19</td></tr> </table>	Element value	P_2	"0"	0,26	"1"	0,45	"2"	0,57	"3"	0,19
Element value	P_2										
"0"	0,26										
"1"	0,45										
"2"	0,57										
"3"	0,19										

Fig. 6c

33 6/10

Element value	P_2	Bit comb.
"0"	0,26	0,1
"1"	0,45	0,0
"2"	0,57	1,0
"3"	0,19	1,1

33'

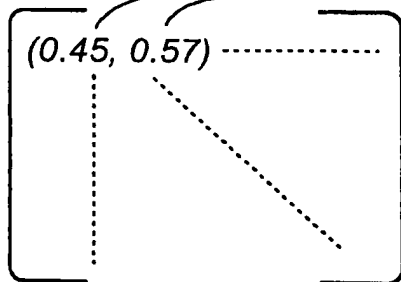
"0"	0,26	0
"1"	0,45	0
"2"	0,57	1
"3"	0,19	1

33''

"0"	0,26	1
"1"	0,45	0
"2"	0,57	0
"3"	0,19	1

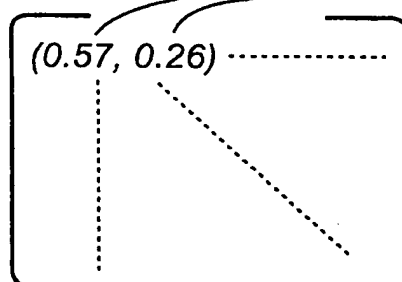
Fig. 7a

$$\begin{aligned} \max(0.26, 0.45) &= 0.45 \\ \max(0.57, 0.19) &= 0.57 \end{aligned}$$



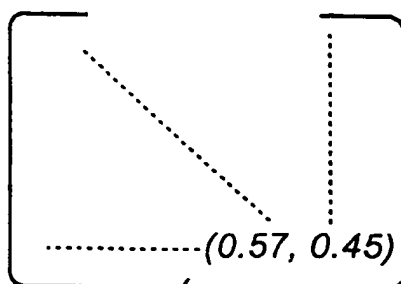
34

$$\begin{aligned} \max(0.45, 0.57) &= 0.57 \\ \max(0.26, 0.19) &= 0.26 \end{aligned}$$

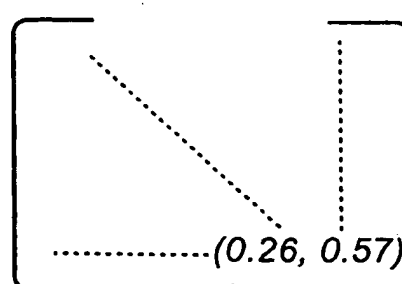


35

Fig. 7b



34'



35'

Fig. 7c

[00000010011111010.....]

39

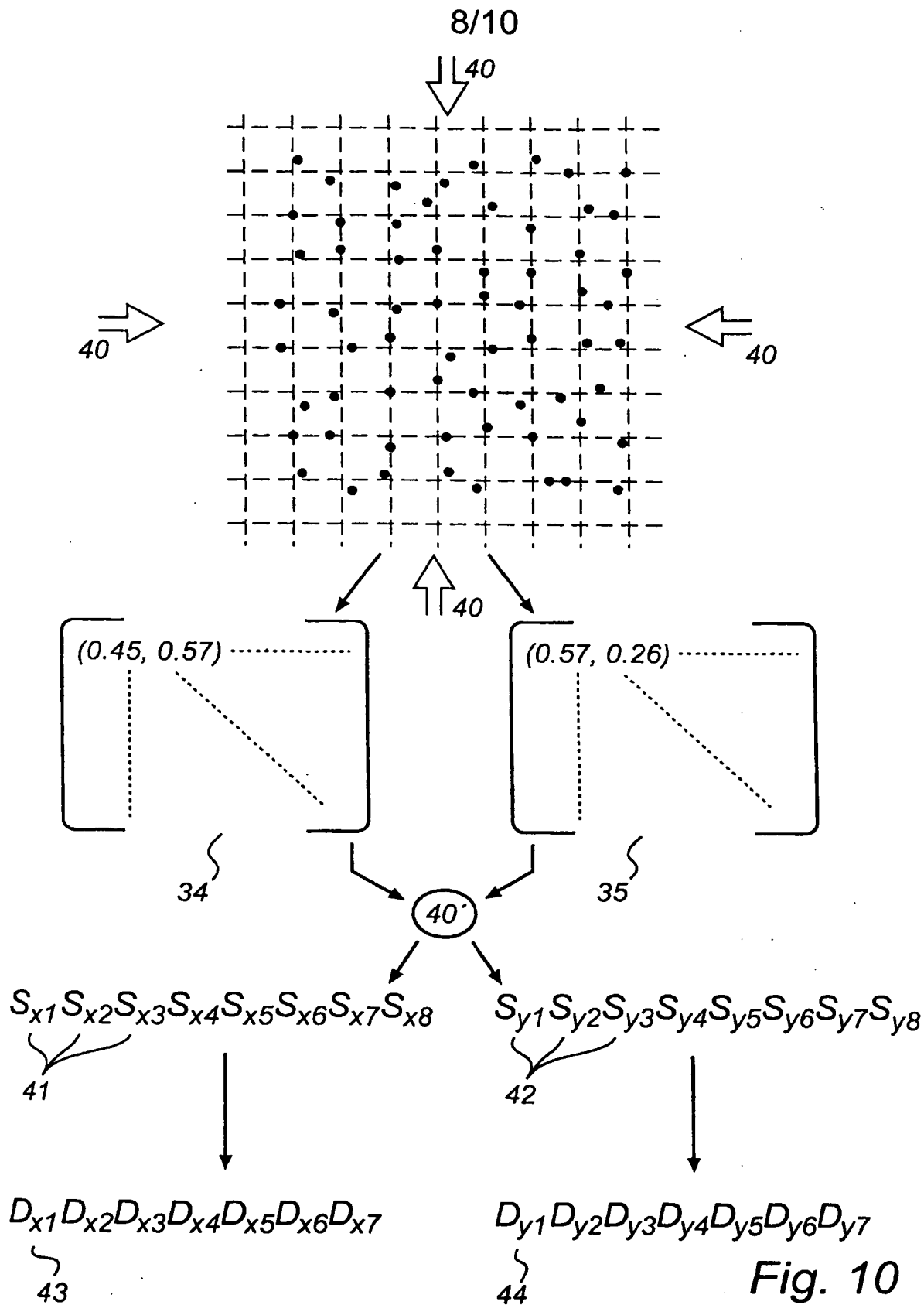
Fig. 8

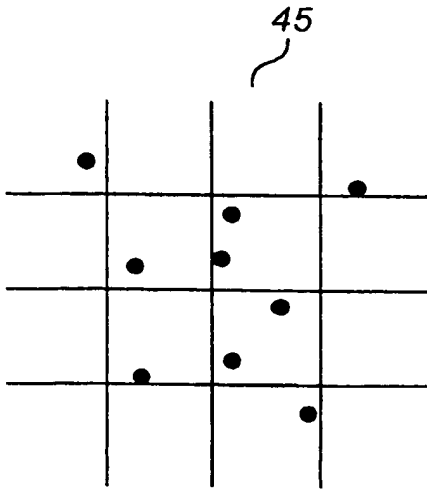
0	0.11, 0.37	0.11
1	0.08, 0.53	0.53
0	0.84, 0.57	0.84
0	0.21, 0.25	0.21
1	0.62, 0.91	0.91
1	0.38, 0.06	0.06
0	0.64, 0.42	0.64
1	0.04, 0.17	0.17

$=6,11 \cdot 10^{-5}$

38

Fig. 9





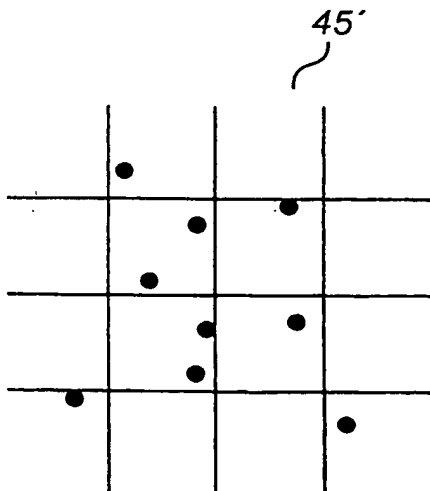
9/10

46

(0.45, 0.27)	(0.31, 0.41)	(0.73, 0.09)
(0.36, 0.14)	(0.73, 0.09)	(0.16, 0.47)
(0.72, 0.09)	(0.55, 0.12)	(0.12, 0.55)

47

(0.45, 0.15)	(0.15, 0.41)	(0.11, 0.73)
(0.36, 0.36)	(0.73, 0.11)	(0.47, 0.24)
(0.12, 0.72)	(0.55, 0.22)	(0.22, 0.55)



48

(0.55, 0.12)	(0.12, 0.55)	(0.09, 0.72)
(0.47, 0.16)	(0.09, 0.73)	(0.14, 0.36)
(0.09, 0.73)	(0.41, 0.31)	(0.27, 0.45)

49

(0.55, 0.22)	(0.22, 0.55)	(0.72, 0.12)
(0.24, 0.47)	(0.11, 0.73)	(0.36, 0.36)
(0.73, 0.11)	(0.41, 0.15)	(0.15, 0.45)

Fig. 11

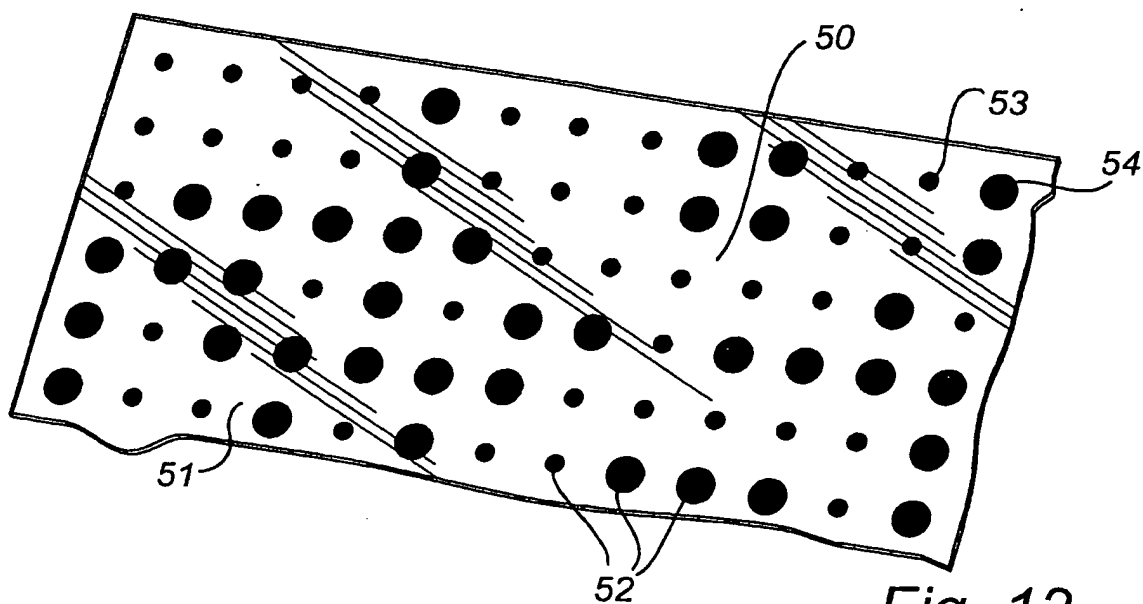


Fig. 12

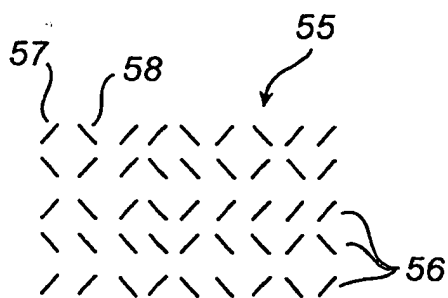


Fig. 13a

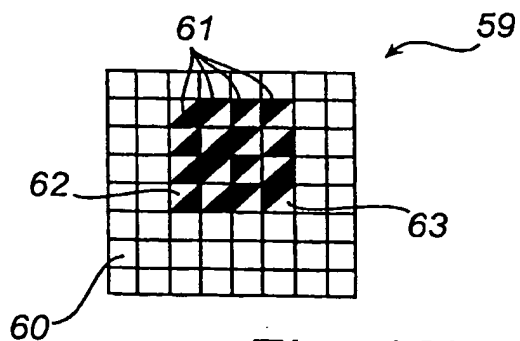


Fig. 13b

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ANOTO AB

Ansökningsnr

Vår referens
SE-2012067

1

REKONSTRUERING AV ETT VIRTUELLT RASTERTekniskt område

Föreliggande uppfinning hänför sig allmänt till identifiering av kodningsmönster i digitala bilder. Närmare bestämt avser uppfinningen ett förfarande, ett datorprogram och ett lagringsmedium för användning vid rekonstruering av ett virtuellt raster ingående i ett sådant kodningsmönster.

Uppfinningen avser även en anordning för avkodning av positioner från digitala bilder av ett kodningsmönster.

Bakgrund till uppfinningen

Det är känt att med hjälp av ett kodningsmönster inbädda information av något slag i ett passivt underlag, såsom ett papper, en skrivtavla eller motsvarande. En lämpligt programmerad skanner, faxmaskin, kamera eller digital penna kan sedan läsa av, återskapa och använda den lokalt i underlaget inbäddade informationen. Exempelvis kan grafisk information på ett underlag kompletteras med inbäddad information som utökar funktionaliteten hos underlaget. Sådan inbäddad information kan avse kommandon, fildata, absoluta positioner, hyperlänkar, etc.

Kodningsmönster är som regel uppbyggda kring någon form av maskinläsbara symboler eller markeringar som är utplacerade i förhållande till rasterpunkter hos ett regelbundet, osynligt raster på underlaget. Exempel på sådana kodningsmönster ges i WO 00/73983, WO 01/26032, US-A-5 477 012 och US-A-5 221 833.

Allmänt, och i synnerhet när kodningsmönstret detekteras med en handhållen apparat, såsom en digital penna, kommer den resulterande bilden att vid sidan av objekt som motsvarar markeringarna, även innehålla störningar i form av brus, geometrisk distorsion, ojämnheter i signalnivå, etc.

Det är således ett allmänt problem att på ett beräkningseffektivt och störningsokänsligt vis identifiera objekten inför avkodningen av kodningsmönstret.

Ovanstående problem och tidigare föreslagna lösningar kommer i det följande att belysas i anslutning till ett speciellt kodningsmönster, vilket beskrivs i detalj i ovanstående patentpublikation WO 01/26032. Kodningsmönstret består av ett raster och markeringar, som är belägna vid varje rasterpunkt. Markeringarna är företrädesvis huvudsakligen runda och är förskjutna i förhållande till rasterpunkterna i endera av fyra ortogonala riktningar. Rastret är virtuellt och är sålunda osynligt för såväl ögat som sensorer.

Ett kodningsmönster av den här typen kan exempelvis användas för att koda absoluta positioner på ett underlag. Därmed möjliggörs digital registrering av information som skrivs och/eller ritas för hand med en digital penna på underlaget. Under pennans förflyttning registreras löpande bilder av kodningsmönstret lokalt vid pennans spets. En delmängd av objekten i var och en av bilderna avkodas till en position. De avkodade positionerna utgör tillsammans en digital beskrivning av pennans förflyttning över underlaget.

I patentpublikationen WO 01/26034 beskrivs en iterativ teknik för rekonstruering av det virtuella rastret i en digital bild av ovanstående kodningsmönster. Vid varje iteration verkställs stegen att identifiera två angränsande objekt, att med kännedom om det ena objektets placering relativt sin rasterpunkt och på basis av ett uppmätt avstånd mellan objekten bestämma det andra objektets rasterpunkt, samt att med utgångspunkt i den sålunda bestämda rasterpunkten söka efter ett nytt objekt inom ett sökområde som definieras med kännedom om rastrets nominella huvudriktningar. När alla objekt har behandlats har man stegat sig objekt för objekt genom bilden och identifierat tillhörande rasterpunkter, och därigenom rekonstruerat det virtuella rastret.

Denna teknik är snabb men förhållandevis känslig för störningar, eftersom den är baserad på lokala beslut kring enskilda objekt och bedömning av dessas lägen relativt tillhörande rasterpunkter.

5 En alternativ teknik beskrivs i WO 01/75783. Här används Fourieranalys för extrahering av riktningsvektorer från en punktmängd, vilken avspeglar objektens placering i den digitala bilden. Först bestäms punktmängdens övergripande huvudvektorer, vilka sedan används vid korrigering av punktmängden med avseende på vridning och skalfel
10 i bildplanet. Därefter beräknas ytterligare huvudvektorer i olika delar av den korrigerade punktmängden, för extrahering av mått på perspektiveffekter och fasförskjutning. Sedan slutkorrigeras punktmängden på basis av dessa mått,
15 varpå det virtuella rastret ges av den resulterande punktmängdens övergripande huvudvektorer. Tekniken är förhållandevis okänslig för störningar, men kan i vissa sammanhang vara önskat beräkningsintensiv.

Sammanfattning av uppfinningen

20 Föreliggande uppfinning har således som ändamål att anvisa en teknik som övervinner ovanstående problem, och närmare bestämt att anvisa en teknik som möjliggör robust och/eller beräkningseffektiv identifiering av ett virtuellt raster i en digital bild av ett kodningsmönster.

25 Dessa och andra ändamål, som kommer att framgå av följande beskrivning, uppnås helt eller delvis genom ett förfarande, ett datorprogram, ett lagringsmedium och en anordning för positionsbestämning enligt efterföljande patentkrav 1, 19, 20 respektive 21. Föredragna utföringsformer definieras i de underordnade patentkraven.
30

Tack vare att uppsättningar av objekten i den digitala bilden matchas mot en cellenhet, som motsvarar ett återkommande, känt grundelement hos rastret, begränsas inverkan av störningar i form av fiktiva objekt, eftersom
35 huvuddelen av dessa inte är placerade i överensstämmelse med cellenheten och därför filtreras bort vid matchningen. Om något enstaka objekt vid matchningen felaktigt

identifieras som godkänt, så påverkas matchningen av kringliggande objekt endast i begränsad omfattning. Matchningen kan dessutom verkställas på beräkningseffektivt vis.

5 Ur beräkningshänseende kan det vara fördelaktigt att, under såväl matchningen som rekonstrueringen, låta objekten i bilden representeras av en punktmängd. Varje objekt kan således representeras av en punkt vars position kan motsvara en tyngdpunkt för objektet, en maximalt
10 eller minimalt luminansvärde hos objektet, etc.

 Ovannämnda cellenhet kan representeras av en polygon vars via sidlinjer förbundna hörn är associerade med vardera ett objekt. En sådan polygon motsvarar således rastrets grundelement med avseende på antalet sidlinjer
15 och antalet associerade markeringar. Däremot kan cellenhetens utsträckning och form avvika från grundelementets dito, för att tillgodose för geometrisk distorsion i den digitala bilden.

 Enligt ett utförande verkställs matchningen som en
20 regelrätt jämförelse mellan uppsättningar av objekt i den digitala bilden och ett antal, med hänsyn till avbildningsförhållandena, möjliga cellenheter av olika utsträckning och form. Alternativt korrigeras först bilden, åtminstone med avseende på vridning i bildplanet, varpå
25 matchningen verkställs genom jämförelse av uppsättningar-na med en cellenhet som är identisk med grundelementet.

 Enligt ett alternativt, föredraget utförande skapas först en datastruktur som anger objektens grannförhållanden. Vid matchningen används sedan datastrukturen för att
30 bland objekten identifiera nämnda uppsättningar. Således används ett grannkriterium för att selektera de uppsättningar av objekt som överhuvudtaget får matchas mot cellenheten, vilket effektiviserar matchningen. Tack vare den förberedande selekteringen kan det också vara möjligt att
35 applicera ett mindre strikt matchningskriterium, såsom att uppsättningen och cellenheten endast behöver ha samma antal objekt, vilket kan minska risken för att korrekta

objekt missas vid matchningen, i synnerhet vid det inledningsvis beskrivna kodningsmönstret vars markeringar är förskjutna relativt sina korsningspunkter. Ovannämnda grannkriterium kan vara att objekten i en uppsättning
 5 skall bilda en cyklisk struktur av grannar och att denna cykliska struktur skall motsvara cellenheten, åtminstone med avseende på antalet därmed associerade objekt. Således kan matchningssteget reduceras till att identifiera cykliska strukturer med ett givet antal objekt, vilket
 10 enkelt kan åstadkommas genom en sekvens av uppslag i datastrukturen.

För att ytterligare öka tåligheten mot störningar kan matchningen föregås av en eliminering av alla objekt som inte är ömsesidiga grannar, dvs matchningen verk-
 15 ställs endast för de objekt som enligt något kriterium har varandra som mest sannolika granne.

Tåligheten mot störningar kan ökas ytterligare genom att det virtuella rastret rekonstrueras på basis av en objektdelmängd, vilken innehåller godkända objekt som
 20 bildar ett sammanhängande område motsvarande flera intill varandra liggande cellenheter. Lämpligen bildas det sammanhängande området att åtminstone omfatta de godkända objekt som parvis förbinds av en sidlinje som är gemensam för två cellenheter.

Rekonstrueringen av det virtuella rastret kan ske genom att de godkända objekten, åtminstone de i ovan-
 nämnda objektdelmängd, tillordnas var sin rasterposition i ett rasterkoordinatsystem på det avbildade underlaget, och att det virtuella rastret rekonstrueras genom att
 30 objektens placering i den digitala bilden kopplas till deras tillordnade rasterposition på underlaget.

Enligt ett exempel beräknas rastrets rasterlinjer genom regressionsanpassning av de godkända objektens placering längs givna riktningar, vilka riktningar kan
 35 extraheras utgående från ovannämnda rasterpositioner.

Enligt ett annat exempel beräknas en homogen transformationsmatris utgående från kopplingen mellan de god-

kända objektens lägen och de motsvarande på underlaget befintliga korsningspunkternas lägen.

Enligt ett utförande för behandling av en sekvens av digitala bilder, korrigeras först en aktuell digital bild för vridning i bildplanet via en första transformations-
 5 matris, varefter ovannämnda homogena transformationsmatris beräknas utgående från den vridningskorrigerade bilden. Inför behandling av en ny aktuell bild, så uppdateras den första transformationsmatrisen på basis av
 10 den senast beräknade homogena transformationsmatrisen. Detta utförande är beräkningseffektivt i det att den första transformationsmatrisen inte behöver beräknas utgående från objekten i varje aktuell bild.

Kortfattad beskrivning av ritningarna

15 Uppfinningen beskrivs nedan i exemplifierande syfte med hänvisning till bifogade ritningar, vilka schematiskt åskådliggör för närvarande föredragna utföringsformer.

Fig 1 är en schematisk vy av en uppsättning om 4 x 4 markeringar i ett kodningsmönster.

20 Fig 2 är en schematisk vy av en handhållen apparat som kan användas för att detektera kodningsmönstret i fig 1.

Fig 3 återger schematiskt en digital bild av ett kodningsmönster av det slag som visas i fig 1.

25 Fig 4 återger en fig 3 motsvarande punktmängd efter kompensation för vridning och skalfel i bildplanet och efter identifiering av grannförhållanden punkterna emellan.

30 Fig 5 illustrerar en lokal omgivning av en punkt och tillhörande sökområden för identifiering av grannpunkter.

Fig 6 visar en datastruktur för registrering av grannförhållanden i den digitala bilden.

35 Fig 7 återger en fig 4 motsvarande punktmängd efter extrahering av punkter med ömsesidiga grannförhållanden, vilka visas som streck i fig 7.

Fig 8 återger en fig 7 motsvarande punktmängd efter extrahering av punkter ingående i cykliska strukturer av givet format.

Fig 9 är ett flödesschema som visar övergripande
5 steg som utförs vid identifiering av den delmängd som
slutligen skall användas vid rekonstrueringen av punkter-
nas lägen relativt ett virtuellt raster.

Fig 10 illustrerar, utgående från punktmängden i fig 8, ett första delsteg vid rekonstrueringen enligt en första utföringsform.

Fig 11 illustrerar slutresultatet av rekonstruktionen enligt den första utföringsformen.

Fig 12 illustrerar, utgående från punktmängden i fig 8, en referenspunktmängd som används vid rekonstrueringen enligt en andra utföringsform.

Fig 13 illustrerar slutresultatet av rekonstrueringen enligt den andra utföringsformen.

Fig 14 är ett flödesschema som visar övergripande steg som kan utföras vid rekonstrueringen enligt den andra utföringsformen.

Fig 15 är en fig 7 motsvarande vy av en alternativ punktmängd efter extrahering av punkter med ömsesidiga grannförhållanden.

Beskrivning av föredragna utföringsformer

25 Nedanstående beskrivning är inriktad på positions-
bestämning utifrån digitala bilder av ett positionskod-
ningsmönster. Positionskodningsmönstret kan vara av
godtyckligt slag, exempelvis något av de inledningsvis
utpekade mönstren. I det följande exemplifieras dock upp-
30 finningen i anslutning till det mönster som beskrivs i
sökandens patentpublikationer WO 01/16691, WO 01/26032
och WO 01/26033. Detta mönster beskrivs nedan i korthet
med hänvisning till fig 1.

Positionskodningsmönstret omfattar ett raster 10 som
35 är uppbyggt av ett antal rasterlinjer 11. Rastret 10 är
virtuellt i så måtto att det varken syns för det mänsk-
liga ögat eller kan detekteras direkt av en anordning som

skall bestämma positioner på ytan. Rastret 10 kan ses som uppbyggt av en mångfald, sida vid sida utlagda, inbördes identiska grundelement, i detta fall kvadrater. Positionskodningsmönstret omfattar också ett flertal markeringar 12, som var och en, beroende på sin placering, representerar ett av fyra värden "1" till "4". Markeringens 12 värde beror på var den är placerad i förhållande till sin nominella position 13. Den nominella positionen 13, som också kan betecknas som en rasterpunkt, representeras av skärningspunkten mellan rasterlinjerna 11.

I exemplet i fig 1 finns fyra möjliga placeringar, en på var och en av rasterlinjerna som utgår från den nominella positionen 13. Förskjutningen från den nominella positionen 13 är lika stor för alla värden. Varje markering 12 är med sin tyngdpunkt förskjuten i förhållande till sin nominella position 13, dvs ingen markering är belägen i den nominella positionen. Det finns vidare en enda markering 12 per nominell position 13.

20 Förskjutningen är företrädesvis $1/6$ av rasterlinje-
avståndet, eftersom det då blir relativt enkelt att av-
göra vilken nominell position som en viss markering till-
hör. Förskjutningen bör vara minst omkring $1/8$ av raster-
linjeavståndet, eftersom det annars kan bli det svårt att
25 bestämma en förskjutning, dvs kraven på upplösning blir
stora. Å andra sidan bör förskjutningen vara mindre än
omkring $1/4$ av rasterlinjeavståndet för att tillhörighet
till nominell position skall kunna bestämmas.

Varje markering 12 utgöres i detta exempel av en mer eller mindre cirkulär prick med en radie som är omkring lika stor som förskjutningen eller något mindre. Radien kan vara mellan 25% till 120% av förskjutningen. Om radien blir mycket större än förskjutningen kan det bli svårt att bestämma rasterlinjerna. Om radien blir för liten behövs större upplösning för att registrera markeringarna. Markeringarna behöver dock inte vara cirkulära eller runda, utan kan ha vilken som helst lämplig form,

såsom kvadratisk, triangulär, elliptisk, fylld, ofylld etc.

Ovan beskrivna mönster kan utformas att koda ett mycket stort antal absoluta positioner. Exempelvis kan
5 mönstret vara sådant att 6 x 6 angränsande markeringar tillsammans kodar ett underlag, i form av en x-koordinat och en y-koordinat. Om en delmängd av mönstret är applicerad på ett underlag kan man åstadkomma en elektronisk representation av det som skrivs eller ritas på under-
10 laget med en penna genom att man löpande bestämmer pennans position på produkten genom avläsning av den lokala kombinationen av markeringar. Denna avläsning kan ske genom optisk detektion.

I fig 2 visas en handhållen apparat 20, nedan kallad penna, som används för optisk detektion av positionskodningsmönstret i fig 1. I det följande beskrivs kort pennans huvudkomponenter enligt ett utförande. För en mer fullständig beskrivning hänvisas till ovannämnda patentpublikationer WO 01/16691, WO 01/26032 och WO 01/26033.
15

Pennan 20 uppvisar ett pennformigt hölje 21 som i sin ena kortände avgränsar en öppning 22. Kortändan är avsedd att ligga an mot eller hållas på litet avstånd från den yta på vilken positionsbestämningen skall ske.
20

En eller flera infraröda lysdioder 23 är inrättade vid öppningen 22 för belysning av det ytområde som skall avbildas, och en IR-känslig areasensor 24, exempelvis en CCD- eller CMOS-sensor, är inrättad att registrera en tvådimensionell bild av ytområdet.
25

Areasensorn 24 är kopplad till en databehandlare 25 som är anordnad att bestämma en position på basis av den av sensorn 24 registrerade bilden. Databehandlaren 25 kan innehålla ett processororgan 25a som är programmerat att bearbeta bilder från sensorn 24, eller från ett sensorn 24 tillordnat minne, för positionsbestämning på basis av
30 dessa bilder.
35

Processororganet 25a kan omfatta en mikroprocessor, såsom en CPU ("Central Processing Unit"), en DSP ("Digi-

tal Signal Processor") eller någon annan programmerbar logisk anordning, såsom en FPGA. Processororganet 25a kan alternativt, eller dessutom, omfatta en hårdvarukrets, såsom en ASIC ("Application-Specific Integrated Circuit") och/eller diskreta analoga och digitala komponenter.

Minnesorganet 25b omfattar företrädesvis olika typer av minne, såsom arbetsminne (RAM), läsminne (ROM/FLASH) och skrivminne (FLASH). På känt vis kan arbetsminnet lagra data under det att denna bearbetas medelst processororganet 25a, kan läsminnet lagra den programkod som exekveras av processororganet 25a i arbetsminnet, och kan skrivminnet lagra resultatet av bearbetningen, såsom positionskoordinater.

Pennan 20 har också en pennspets 26 som avsätter markeringsvätska på underlaget. Därmed kan användaren skriva fysiskt på underlaget samtidigt som det skrivna registreras digitalt via optisk detektion av positionskodningsmönstret. Markeringsvätskan är lämpligen transparent för infrarött ljus, medan positionskodningsmönstrets markeringar 12 (fig 1) är absorberande för infrarött ljus. Därmed undviks att markeringsvätskan stör detektionen av mönstret.

När pennan 20 förs över ett positionskodat underlag registrerar således areasensorn 24 en följd av digitala gråskalebilder som överförs till databehandlaren 25 för positionsbestämning. I bilderna framträder markeringarna 12 (fig 1) som mörka objekt mot en ljus bakgrund. Vanligen täcker varje objekt flera bildelement.

För att kunna avkoda en bild måste databehandlaren rekonstruera det virtuella rastret och fastställa ett givet antal objekts placeringar relativt detta.

Inför rekonstrueringen av det virtuella rastret verkställer databehandlaren först en sk segmenteringsprocess för att isolera objekten från bakgrunden i gråskalebilden och därigenom reducera mängden data att behandla i efterföljande steg. Detta kan ske genom en för fackmannen välkänd trösklingsoperation, vilken resulterar

i en binär bild. För att ytterligare reducera mängden data kan databehandlaren extrahera en punktmängd från den binära bilden, t ex genom beräkning av tyngdpunkten för respektive objekt. Slutresultatet av segmenteringsprocessen kan således vara en binär bild (bitmap), där varje objekt identifieras av ett bildelement (pixel), eller någon annan datastruktur som innehåller en lägesbestämning för varje objekt med pixel- eller subpixelupplösning.

Segmenteringsprocessen kommer i allmänhet också att identifiera fiktiva objekt, dvs objekt utan motsvarighet i den avbildade delmängden av positionskodningsmönstret, exempelvis som följd av brus, belysningsvariationer, eller artefakter (smuts, ojämnheter, etc) hos det positionskodade underlaget. Sådana fiktiva objekt kan störa avkodningsprocessen.

Fig 3 visar schematiskt en digital bild av ovan beskrivna kodningsmönster. I fig 3 indikeras objekt med ringar och motsvarande punktmängd med kryss. Det virtuella rastret 10 är också inritat för att underlätta förståelsen. Uppenbarligen är den digitala bilden registrerad med vridning och kraftig snedställning av sensorn relativt det positionskodade underlaget. Det må understrykas att fig 3 är ett schematiskt exempel, och att antalet n objekt i det praktiska fallet kan vara betydligt större. Även om varje position kodas av 36 (6×6) objekt så omfattar varje digital bild i allmänhet fler objekt, typiskt $n = 100-200$.

Efter segmenteringen underkastas den binära bilden en korrigeringsprocess, vilken resulterar i en punktmängd väsentligen utan vridning i bildplanet. Detta kan åstadkommas via Fourieranalys av punktmängden, såsom beskrivs i detalj i ovannämnda patentpublikation WO 01/75783. Fourieranalysen resulterar i övergripande huvudvektorer för punktmängden, dvs övergripande riktningar och avstånd i den binära bilden. Därefter beräknas en linjär transformationsmatris som överför huvudvektorerna till resul-

tatvektorer vars riktning och längd väsentligen motsvarar originalrastret (fig 1), i detta fall inbördes ortogonala vektorer med längdförhållande 1:1. Punktmängden korrigeras därefter för vridning och skalfel genom att transformationsmatrisen opereras på den ursprungliga punktmängden. I fig 4 visas resultatet av korrigeringsprocessen för punktmängden i fig 3. Av tydlighetsskäl visas även det virtuella rastret 10, som ju ännu inte är rekonstruerat. Det framgår att en icke-linjär komponent, dvs perspektivförvrängning, kvarstår hos den korrigerade punktmängden.

Härefter verkställer databehandlaren en sökprocess, vilken syftar till att identifiera punkternas grannförhållanden. Närmare bestämt eftersöks, för varje punkt i punktmängden, en grannpunkt i givna sökriktningar.

Sökprocessen illustreras närmare i fig 5, utgående från två resultatvektorer v_1 , v_2 enligt ovan. I sökprocessen används fyra, utgående från dessa resultatvektorer v_1 , v_2 definierade, sökvektorer: v_1 , v_2 , $v_3 = -v_1$ och $v_4 = -v_2$. Varje sökvektor är sin tur tillordnad ett sökområde I-IV, vars utsträckning är satt med kännedom om kodningsmönstrets uppbyggnad. Sökområdena är lämpligen tillräckligt stora för att säkerställa detektion av en punkt tillhörande en angränsande rasterkorsning, men tillräckligt små för att undvika detektion av punkter tillhörande andra rasterkorsningar (jfr fig 1). I det aktuella kodningsmönstret är varje markering förskjuten $1/6$ av rasterlinjeavståndet, varför det minsta avståndet mellan markeringarna är $2/3$ rasterlinjeavstånd (markeringar som är förskjutna i riktning mot varandra). Perspektiveffekter i bilden kan reducera detta avstånd, varför sökområdenas radie i föreliggande exempel har satts till ca $1/2$ rasterlinjeavstånd.

Utgående från en punkt A i fig 5 identifieras en grannpunkt D i sökområdet I, två potentiella grannpunkter B och C i sökområdet II, och inga grannpunkter i sökområdena III-IV.

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Ovannämnda skelett förfinas dock ytterligare i två kontrollsteg innan databehandlaren verkställer rekonstrueringen av rastret.

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v_3 , om den tredje grannen har en fjärde granne i den fjärde sökriktningen v_4 , och om den fjärde grannen är identisk med den aktuella punkten. I så fall extraheras dessa punkter och identifieras som ingående i en cell-
 5 enhet. I fig 8 visas de cellenheter som identifierats utgående från fig 7.

Härefter klassificeras länkarna mellan punkterna. Om länken ingår som en sidlinje i två cellenheter, klassificeras länken som stark (steg 902), annars som
 10 svag (steg 903).

Klassificeringen används sedan för identifiera ett sammanhängande område av skelettet att använda vid rekonstrueringen. Detta sker genom att databehandlaren väljer en startpunkt (steg 904) bland de i cellenheter
 15 ingående punkterna och identifierar alla starka punkter, dvs punkter som kan nås från startpunkten via starka länkar (steg 905). Därefter identifierar databehandlaren alla svaga punkter, dvs punkter som kan nås från de starka punkterna via en och endast en svag länk (steg 906).
 20 Databehandlaren bildar en första komponent eller delmängd av de identifierade starka och svaga punkterna (steg 907), och upprepar sedan ovanstående sökning för andra startpunkter (steg 908). Dessa startpunkter kan lämpligen väljas bland de punkter som ännu inte ingår i någon kom-
 25 ponent, eller åtminstone bland de punkter som ännu inte klassats som starka. I det sistnämnda fallet kan således svaga punkter ingå i flera komponenter. När alla möjliga startpunkter testats, utväljs den komponent som innehåller flest punkter, alternativt flest starka punkter
 30 (steg 909).

I fig 8 visas resultatet av det andra kontrollsteget för de från skelettet i fig 7 extraherade punkterna, utgående från startpunkten S. Starka och svaga länkar visas med dubbelstreck respektive enkelstreck, och starka och
 35 svaga punkter visas med fyllda respektive ofyllda cirk-
 lar.

I fig 8 visas också att de starka och svaga punkterna, åtminstone i den utvalda komponenten, åsätts var sin rasterposition i ett rasterkoordinatsystem som kan, men inte behöver, vara centrerat i startpunkten S. Varje rasterposition ges i exemplet av två rasterkoordinater i form av heltal. Dessa rasterpositioner används för att koppla punkterna i komponenten till det ursprungliga kodningsmönstrets rasterkorsningar, såsom kommer att beskrivas närmare nedan.

Ovanstående klassificering av länkarna syftar till att minimera uppkomsten av fel när en komponent bildas av flera lokalt identifierade cellenheter. I fig 15 visas ett exempel på ett skelett av ömsesidiga grannförhållanden mellan punkter/objekt i en bild. Även om varje cellenhet verkar korrekt identifierad i sin lokala omgivning, så innehåller cellenheterna som helhet ett geometriskt fel. Om komponenten byggs upp på grundval av endast starka länkar, så minimeras denna typ av geometriska fel eftersom de starka länkarna ingår i två cellenheter och därmed är bestämda med större säkerhet än de svaga länkarna.

Eftersom den efterföljande rekonstrueringen förbättras med antalet punkter som ingår i den utvalda komponenten, så kan man dock tillåta svaga länkar att ge bidrag till komponenten med en ytterligare punkt, såsom beskrevs i ovanstående exempel. Även om det inte framgår av exemplet i fig 8, kan det vara lämpligt att reducera inverkan av de svaga punkterna relativt de starka punkterna, t ex genom att de svaga punkterna ges en rasterposition som är bestämd i endast en dimension, och närmare bestämt så, att en svag punkt tillordnas den rasterkoordinat som är gemensam för den svaga punkten och den starka punkt som länkar den svaga punkten till den aktuella komponenten.

Härefter skall det virtuella rastret rekonstrueras utifrån den utvalda komponenten i fig 8.

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WO 01/16691, WO 01/26032 och WO 01/26033, vilka inför-
livas härigenom genom denna hänvisning.

Enligt en andra utföringsform verkställer databehandlaren rekonstrueringen genom beräkning av en homogen transformationsmatris. I detta fall jämförs varje punkt i den utvalda komponenten, såsom visas i fig 8, med motsvarande rasterkorsning i ett idealt raster, såsom visas i fig 12. Härvid används rasterpositionerna för att identifiera punkter och motsvarande rasterkorsningar, såsom också indikeras i fig 8 och 12. Därmed kan ett ekvations-system ställas upp innehållande tolv obekanta parametrar (hos transformationsmatrisen) och ekvationer som till antalet är dubbelt så många som punkterna i den utvalda komponenten, på liknande vis som beskrivs i "Digital Image Processing" av R.F. Gonzalez och R.E. Woods, Addison-Wesley, 1992, pp 67-68. Med kännedom om att samtliga punkter härrör från ett och samma geometriska plan (dvs underlaget) kan antalet obekanta parametrar reduceras till åtta.

20 Det finns en mängd olika kända numeriska metoder för lösning av dylika överbestämda ekvationssystem. Det för närvarande föredragna utförandet är baserat på en minsta-kvadrat-anpassning.

Det kan te sig oväntat att en korrekt homogen trans-
 25 formationsmatris kan beräknas genom koppling av punkterna
 i fig 8 till rasterkorsningarna i fig 12, eftersom punkt-
 erna genom sina förskjutningar (jfr fig 1) inte exakt
 motsvarar rasterkorsningarna. Den beräknade transforma-
 tionsmatrisen representerar dock någon form av medelvärde
 30 över ett stort antal punkter, varför förskjutningarna
 matematiskt väsentligen tar ut varandra.

När den homogena transformationsmatrisen har beräknats opereras den på den utvalda komponentens punkter, vilka då överförs till sina korrekta placeringar i förhållande till ett rekonstruerat raster vars rasterkorsningar ges av rasterpositionerna, såsom indikeras i fig 13.

I det följande beskrivs i anslutning till fig 14 övergripande förfarandesteg som utförs av databehandlaren vid behandling av en sekvens av gråskalebilder.

Först inläses en aktuell gråskalebild (steg 141), vilken via en segmenteringsprocess bildar en aktuell binär bild (steg 142). Sedan extraheras lämpligen en aktuell punktmängd från den aktuella binära bilden. Därefter beräknas en linjär transformationsmatris LTM, t ex via Fourieranalys av den aktuella punktmängden (steg 143). Den linjära transformationsmatrisen används sedan för att korrigera den aktuella punktmängden för vridning och ev skalfel (steg 144). Härefter verkställs sökprocessen (steg 145), samt de första och andra kontrollstegen (steg 146-147), vilka resulterar i en utvald komponent, dvs en utvald delmängd punkter. Slutligen beräknar databehandlaren en homogen transformationsmatris HTM på basis av den utvalda komponentens punkter (steg 148), varpå den homogena transformationsmatrisen opereras på komponentens punkter för att skapa ett rekonstruerat raster med tillhörande punkter (steg 149), vilka sedan avkodas (steg 150).

Vid digitalisering av handskrift bör denna för korrekt återgivning registreras med en samplingstakt av ca 50-100 Hz. Vid denna samplingstakt sker dock förhållandevis små förändringar i vridning och snedställning av pennan mellan påföljande bilder. Detta kan utnyttjas för att minimera beräkningsarbetet med att ta fram en ny linjär transformationsmatris LTM för en efterföljande gråskalebild. I stället för att verkställa en förhållandevis tids- och beräkningskrävande analys, t ex via Fouriertransformering, kopieras de linjära parametrarna från den homogena transformationsmatrisen HTM in i den linjära transformationsmatrisen LTM (steg 143), varpå den sålunda uppdaterade transformationsmatrisen används under korrigeringsprocessen (steg 144). Därmed kan processorkraft frigöras i databehandlaren för andra beräkningar, t ex avkodning.

Ovanstående förfarande kan realiseras av programkod som exekveras i den digitala pennans processororgan, eller i en till pennan kopplad, extern behandlingsenhet. Programkoden kan tillhandahållas på ett lagringsmedium, t ex i form av en diskett, en CD-ROM, eller propagerande 5 signaler via ett datornätverk. Alternativt kan förfarandet realiseras av en hårdvarukrets och/eller diskreta analoga/digitala komponenter, eventuellt i kombination med exekvering av programkod enligt ovan.

10 Det må påpekas att det sökta patentskyddets omfattning ej begränsas av ovan beskrivna utföringsexempel. Uppfinningen kan varieras och ändras på ett flertal sätt inom ramen för de bifogade patentkraven.

Exempelvis är den uppfinningsenliga tekniken applicerbar även för kodningsmönster baserade på andra grund- 15 element, såsom hexagoner, rektanglar, trianglar etc, eller andra markeringar, såsom streck, trianglar, två-dimensionella streckkoder etc, placerade med eller utan förskjutning relativt korsningspunkterna hos ett virtuellt rastermönster. 20

Vidare må påpekas att ovanstående korrigeringsprocess inte är knuten till användning av Fouriertransformer, utan kan verkställas med någon annan för syftet vedertagen metod, såsom Hough-transformer, Walsh-transformer etc. För övrigt är det inte ens nödvändigt att 25 verkställa någon korrigering, utan sökprocessen kan verkställas på basis av de övergripande huvudvektorerna i stället för resultatvektorerna. En inledande korrigering kan dock underlätta implementeringen av den efterföljande sökprocessen, eftersom samma sökområden kan användas för 30 alla punkter och alla bilder.

Enligt ett ytterligare alternativ utan korrigeringsprocess verkställs den andra kontrollprocessen som en regelrätt geometrisk matchning av punktmängden mot en 35 uppsättning olika möjliga cellenheter. Databehandlaren kan exempelvis vara anordnad att, på basis av ett aktuellt beräknat perspektiv, hämta möjliga cellenheter från

ett bibliotek i sitt minnesorgan. Exempelvis kan en kvadratsumma av avvikelserna mellan punkter och motsvarande hörn hos respektive cellenhet användas som matchningskriterium, varvid kvadratsumman bör understiga ett gränsvärde för att överensstämmelse skall anses föreligga.

Enligt ett annat tänkbart alternativ sker en inledande korrigeringsprocess, varefter en regelrätt geometrisk matchning verkställs av punktmängden mot kodningsmönstrets kända grundelement. Även här kan en kvadratsumma av avvikelserna mellan punkter och hörnpositioner användas som matchningskriterium.

7. Förfarande enligt krav 5 eller 6, varvid objekt-
35 delmängden bildas att innehålla det största möjliga
antalet godkända objekt.

8. Förfarande enligt något av föregående krav, omfattande det inledande steget att skapa en datastruktur över objektens grannförhållanden, varvid matchningssteget omfattar att med användning av datastrukturen identifiera
5 nämnda uppsättningar.

9. Förfarande enligt något av föregående krav, ytterligare omfattande stegen att i den digitala bilden bestämma huvudvektorer som återger dess övergripande rasterlinjeriktningar och rasterlinjeavstånd, att på
10 basis av huvudvektorerna identifiera objektens grannförhållanden genom att för varje objekt identifiera ett annat objekt som granne i respektive rasterlinjeriktning, och att därefter verkställa matchningssteget utgående från objektens grannförhållanden.

15 10. Förfarande enligt krav 8 eller 9, varvid de i en uppsättning ingående objekten identifieras som godkända om de som grannar bildar en cyklisk struktur som motsvarar cellenheten, åtminstone med avseende på antalet därmed associerade objekt.

20 11. Förfarande enligt något av föregående krav, omfattande steget att tillordna de godkända objekten var sin rasterposition i ett rasterkoordinatsystem på det avbildade underlaget, varvid det virtuella rastret rekonstrueras på basis av objektens placering i den digitala
25 bilden och deras tillordnade rasterposition på underlaget.

12. Förfarande enligt något av föregående krav, varvid steget att rekonstruera det virtuella rastret omfattar att beräkna rasterlinjerna genom regressionsanpassning av de godkända objektens placering längs givna
30 riktningar.

13. Förfarande enligt krav 5 och 12, varvid riktningarna ges av rasterpositioner, företrädesvis av heltalskoordinater i ett rasterkoordinatsystem, vilka
35 rasterpositioner åsätts de godkända objekten i samband med steget att bilda objektdekmängden.

14. Förfarande enligt något av kraven 1-11, varvid steget att rekonstruera det virtuella rastret omfattar att beräkna en homogen transformationsmatris utgående från lägesförhållandena mellan de godkända objekten och de motsvarande på underlaget befintliga korsningspunkterna, vars inbördes placering är definierade av grundelementet.

15. Förfarande enligt krav 5 och 14, varvid lägesförhållandena ges av rasterpositioner, företrädesvis av heltalskoordinater i ett rasterkoordinatsystem, vilka rasterpositioner åsätts de godkända objekten i samband med steget att bilda objektldelmängden.

16. Förfarande enligt krav 15, för behandling av en sekvens av digitala bilder, omfattande det inledande steget att via en första transformationsmatris korrigera en aktuell digital bild för vridning i dess plan, att beräkna den homogena transformationsmatrisen utgående från den sålunda vridningskorrigerade bilden, och att uppdatera den första transformationsmatrisen inför behandling av en nästföljande digital bild.

17. Förfarande enligt krav 16, varvid steget att uppdatera den första transformationsmatrisen omfattar att extrahera relevanta linjära parametrar från den homogena transformationsmatrisen.

18. Förfarande enligt något av föregående krav, varvid matchningssteget verkställs endast för de objekt som är ömsesidiga grannar.

19. Datorprogram, vilket innefattar programkod som när den exekveras i en dator bringar datorn att genomföra ett förfarande enligt något av kraven 1-18.

20. Lagringsmedium vilket är avläsbart medelst en dator och på vilket är lagrat ett datorprogram som när det exekveras i en dator bringar datorn att genomföra ett förfarande enligt något av kraven 1-18.

21. Anordning för positionsavkodning, omfattande en signalbehandlare (25) som är anordnad att beräkna en position på basis av information som bestämts från en

medelst en sensor (24) genererad digital bild av ett del-
område av ett positionskodningsmönster, vilket omfattar
markeringar (12) som var och en är associerad med en
respektive korsningspunkt (13) för rasterlinjer (11)

- 5 tillhörande ett virtuellt raster (10), varvid signal-
behandlaren (25) vidare är anordnad att inför positions-
beräkningen rekonstruera det virtuella rastret (10) ut-
gående från objekt i den digitala bilden, vilka objekt
åtminstone delvis återger nämnda markeringar, k ä n n e -
10 t e c k n a d av att signalbehandlaren (25) är anordnad
att matcha uppsättningar av objekten mot en cellenhet,
vilken motsvarar ett återkommande, känt grundelement hos
nämnda raster (10), att när en uppsättning överensstämmer
med cellenheten identifiera de i uppsättningen ingående
15 objekten som godkända, och att rekonstruera det virtuella
rastret (10) på basis av de godkända objektens inbördes
placering.

SAMMANDRAG

Ett förfarande syftar till att utgående från objekt
5 i en digital bild identifiera ett virtuellt raster ingående i ett kodningsmönster. Objektet i bilden återger åtminstone delvis markeringar på ett underlag, varvid varje markering är associerad med en respektive korsningspunkt för rasterlinjer tillhörande det virtuella
10 rastret. Förfarandet omfattar stegen att matcha uppsättningar av objektet mot en cellenhet, vilken motsvarar ett återkommande, känt grundelement hos nämnda raster; att när en uppsättning överensstämmer med cellenheten identifiera de i uppsättningen ingående objektet som
15 godkända; och att rekonstruera det virtuella rastret på basis av de godkända objektets inbördes placering.

Ett datorprogram, ett lagringsmedium samt en anordning för positionsbestämning beskrivs också.

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35 Publiceringsbild: fig 14

1/9

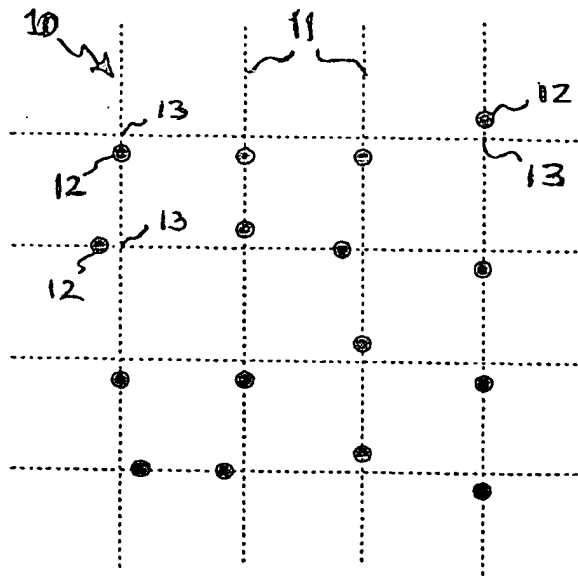


Fig 1

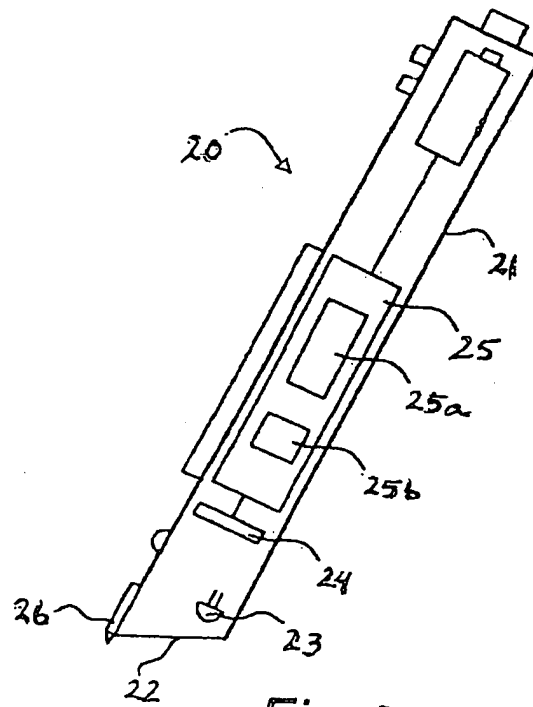


Fig 2

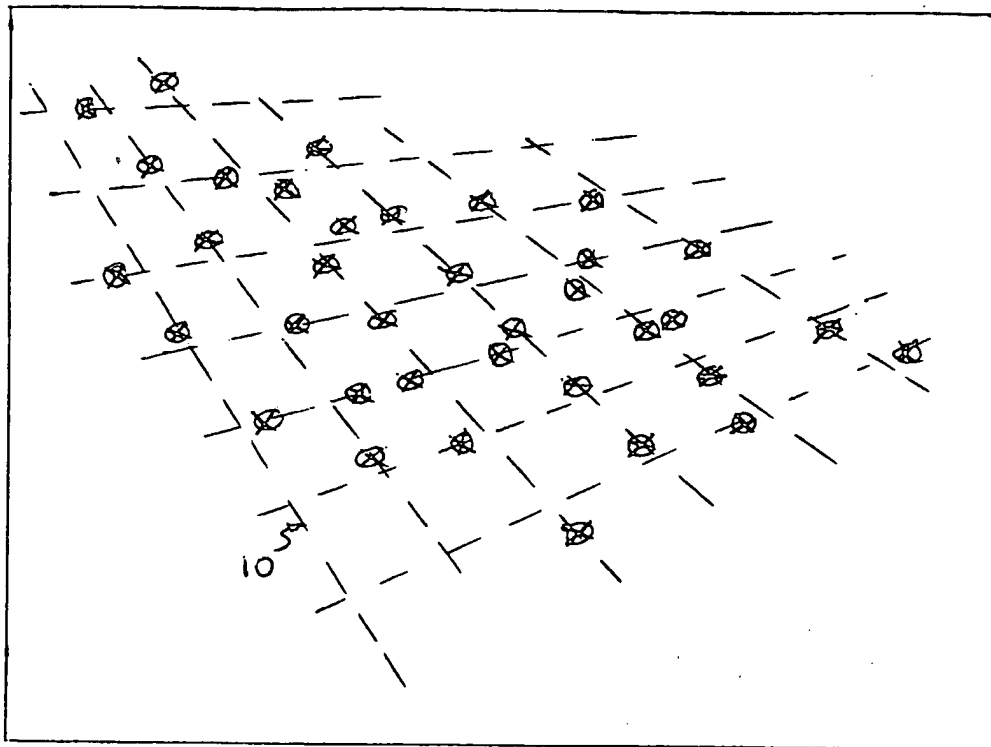


Fig 3

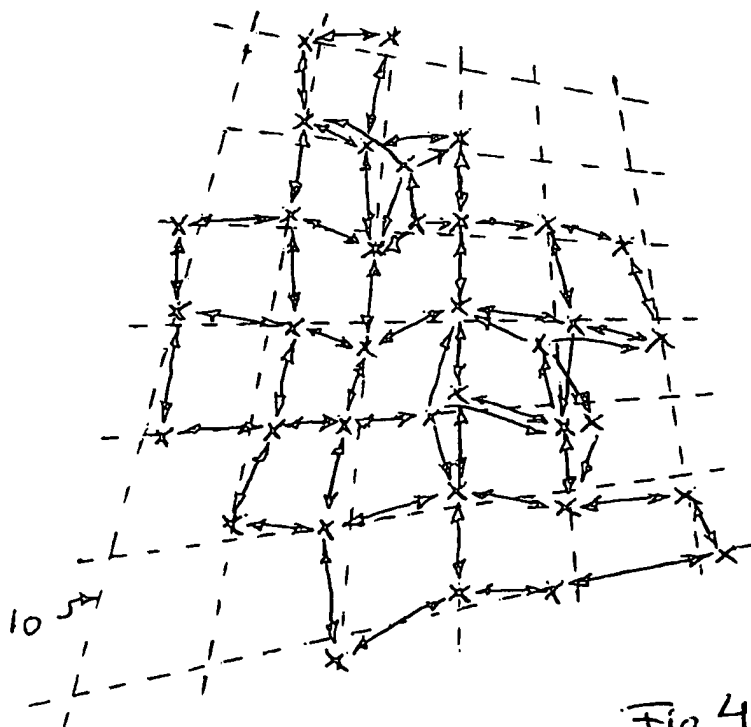


Fig 4

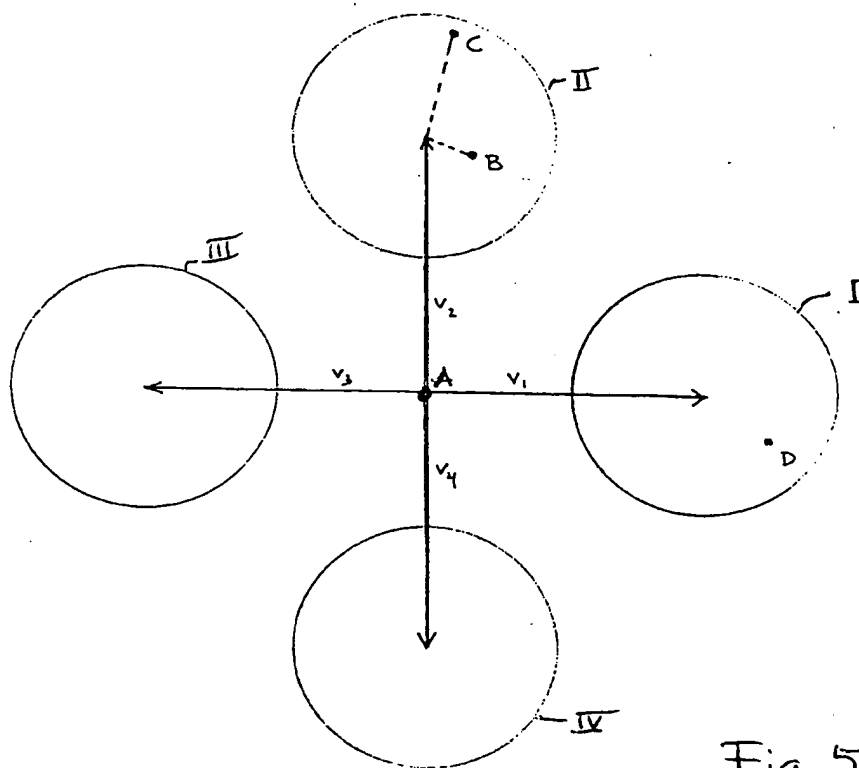


Fig 5

n {

	v_1	v_2	v_3	v_4
$A \rightarrow$	D	B	—	—

Fig 6

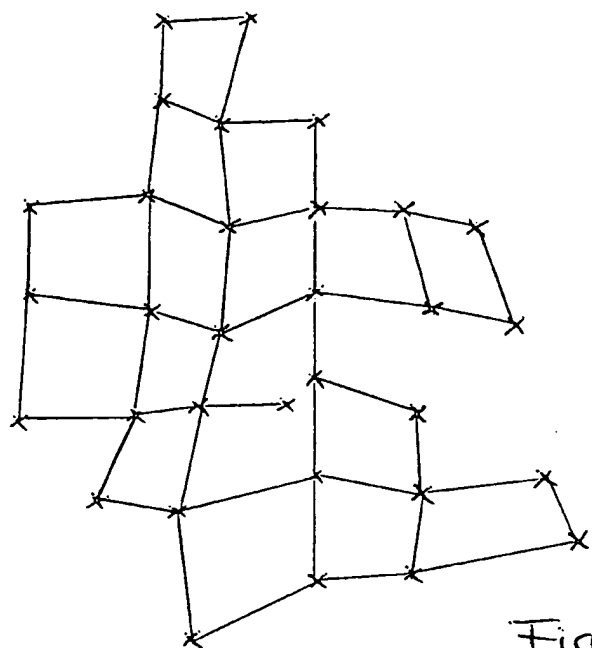


Fig 7

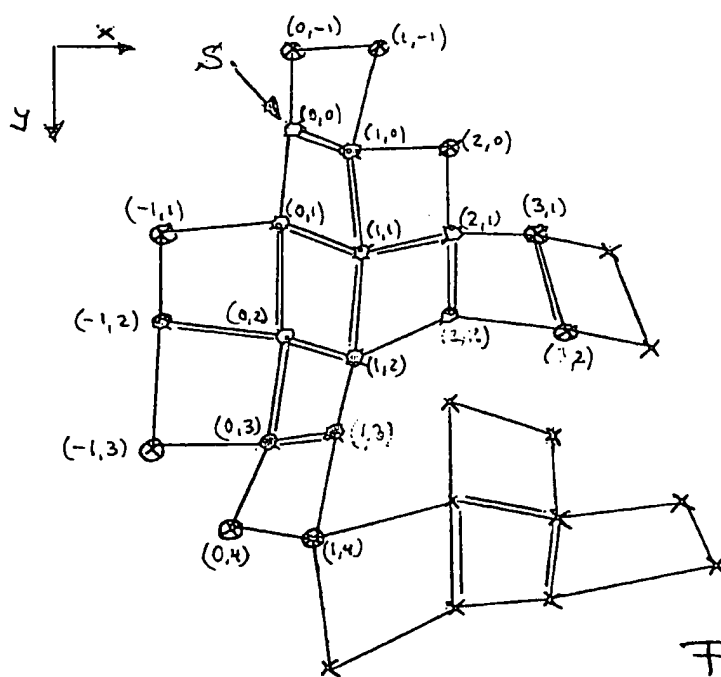


Fig 8

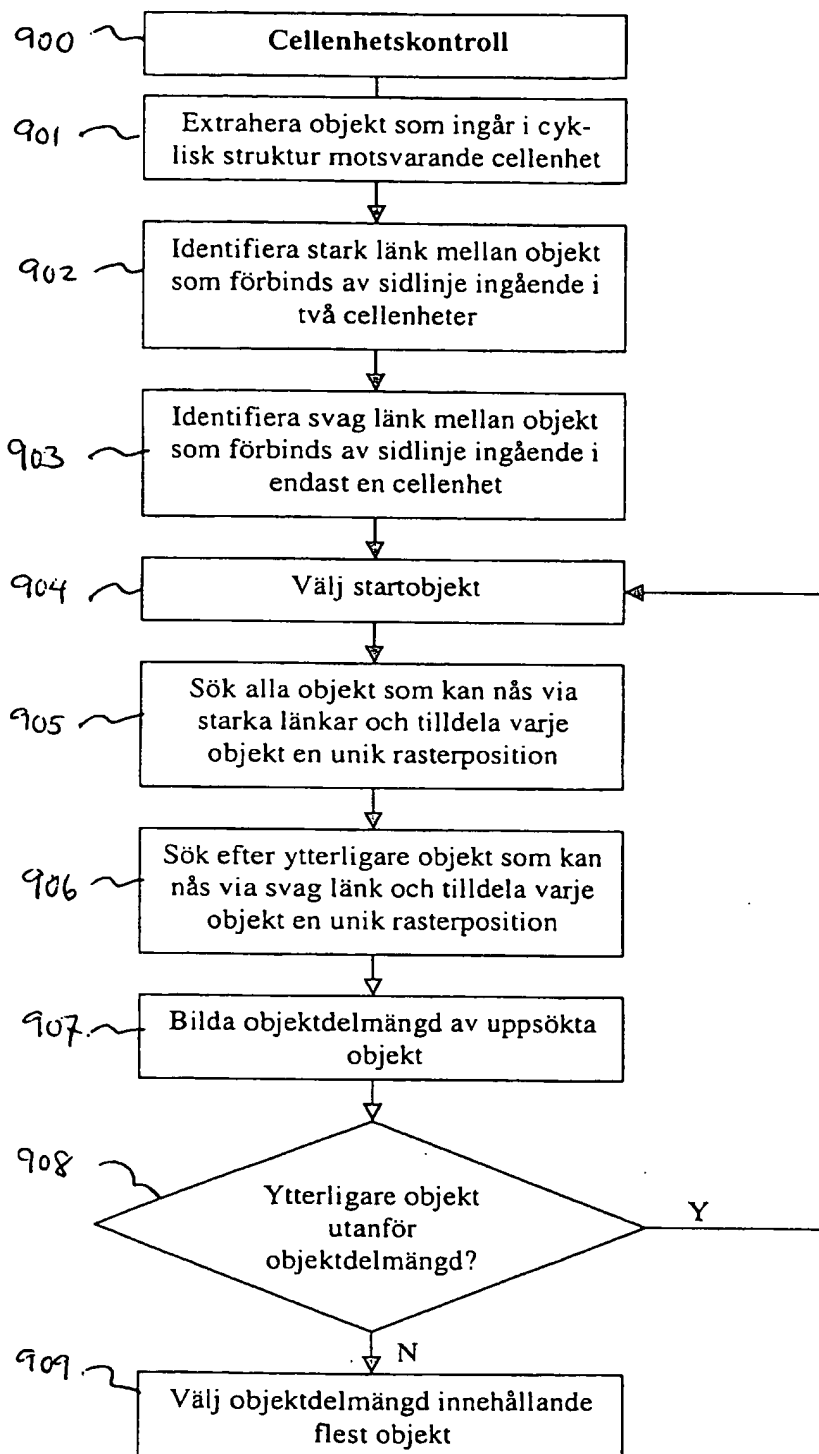


Fig 9

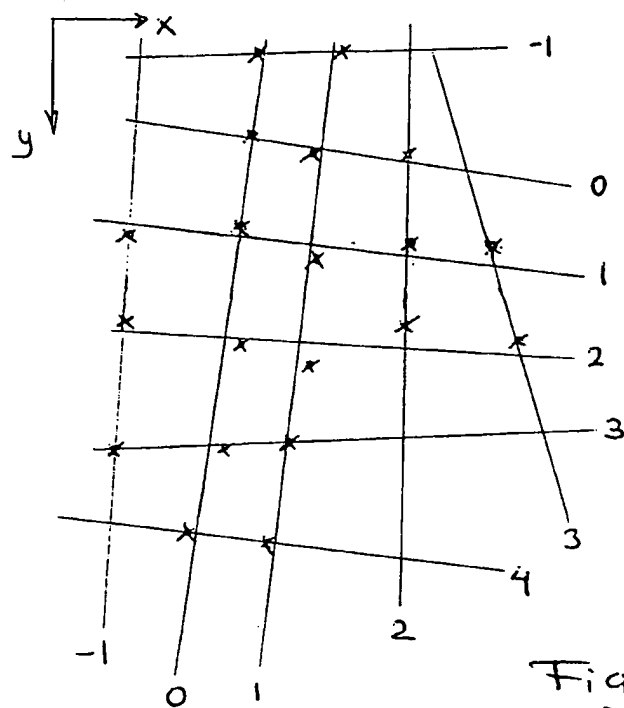


Fig 10

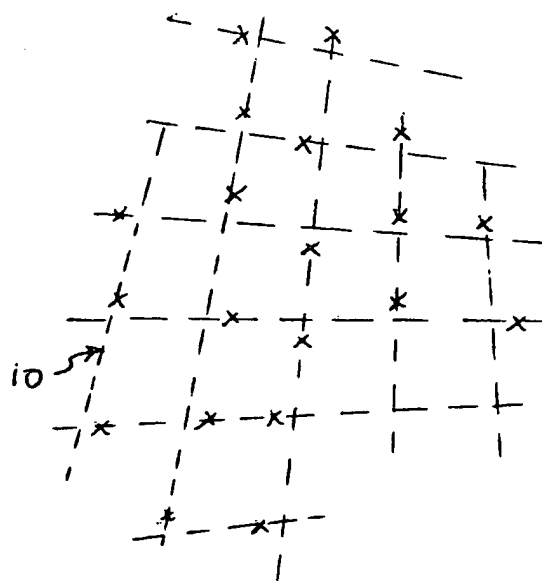


Fig 11

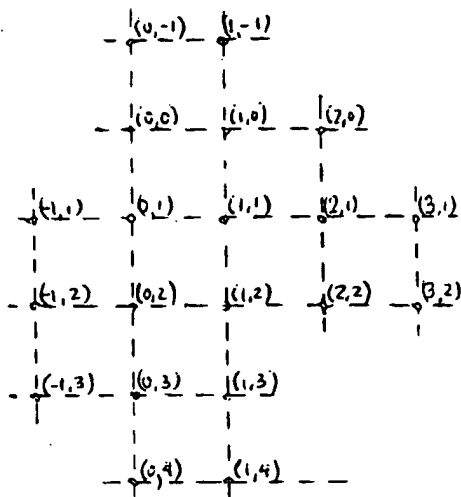


Fig 12

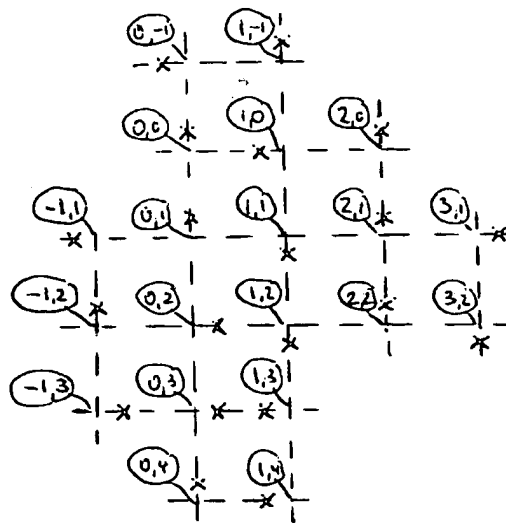


Fig 13

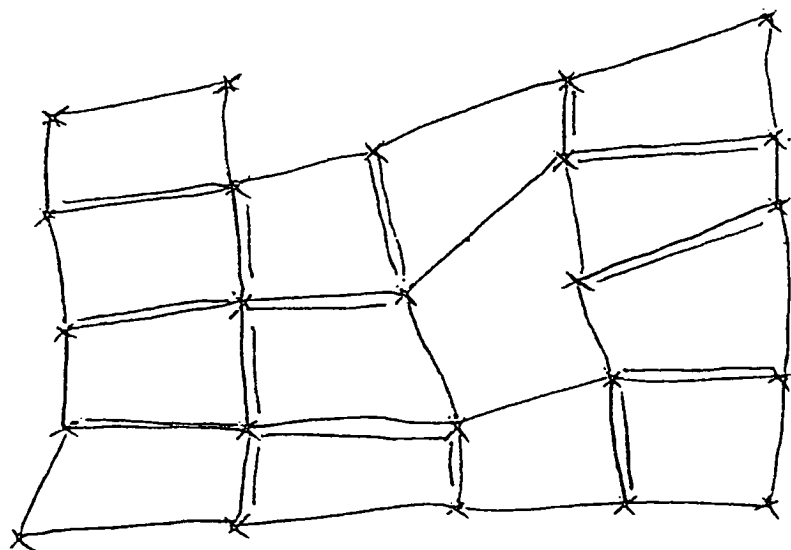


Fig 15